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The Blast Furnace and Steel Plant

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Attitude of Mind

NOTHING is more significant than the changes which occur in our way of looking at things. What seemed impossible yesterday becomes accepted practice tomorrow; almost imperceptibly we adapt ourselves to the changed necessity.

Some three years ago a body of ultimately experienced steel executives discussed the possibility of the shorter day in the steel industry; opinions were widely divergent; the clearest thinker summed the situation up by saying, "The short day will come when it is economically possible." 1923 saw the broad adoption of this form of labor throughout the steel industry and results to date indicate that it is economically possible; certain benefits outweigh the apparent difficulties.

A year ago we heard great clamor against restricted immigration. Much of it has already subsided; forced efficiencies have produced record outputs and have paved the way for further records; labor shortage is now accepted as a blessing in disguise.

January, 1923, was ushered in with much enthusiasm as to business possibilities, but after the mid year many minds clouded with the remnant apprehension of 1921 and 1922, failed to read the sequences of published reports which emphasized true conditions.

The new year begins with most of this forgotten—we have accustomed ourselves to European cataclysm, to presidential year presentiments, and all the other bugaboos. Some 40,000,000 tons of steel must be made, and we might as well make it and enjoy the satisfaction of seeing everybody busy at reasonable hours and worth while wages, earned under livable conditions. That seems to be the prevailing conclusion.

Mental flexibility is surely the best American asset with which to start the New Year.

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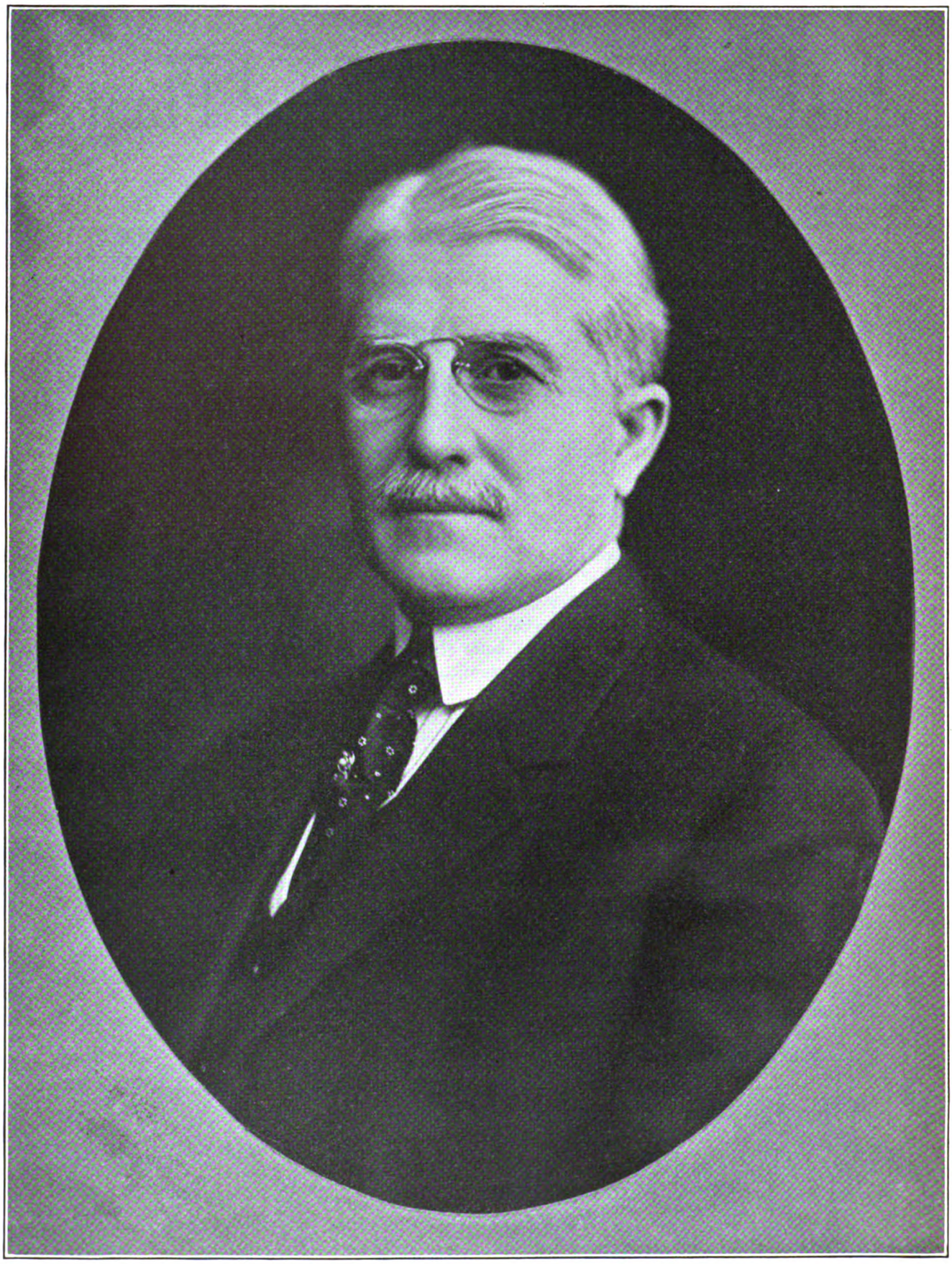

Mr. George M. Verity

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The Human Element

Tremendous Changes Influenced by Corporate Expansions Have Revolutionized the Personal Equation in Industry

By GEORGE M. VERITY*

WHILE the making and paying of dividends might be considered the one great crucial test of industry, there are many serious problems that must be successfully solved before that result is secured. Of all the factors to be reckoned with, there is none more important than industry's contact with and influence over human life, because the very source of all achievement is found in life and not in machinery and equipment.

Properties may be acquired and plants may be constructed, but in a final analysis the human element and everything that influences it for good or ill, represents the greatest single factor that makes for success or failure in business.

Many industrial and commercial leaders are now creating a new tie between management and men, by providing a way for joint ownership of all those who are in any way contributing to the success of the business. In other words, the doors have been opened for the commonest laborer to become a part owner of the capital invested and to occupy the dual capacity of employer and employe. Many situations can be found where this policy has unquestionably proved to be a substantial factor in the creation of industrial and commercial stability.

This new move is fundamentally sound, for such amalgamation of the human factors in business serves to underwrite an industry with loyalty insurance. Through common ownership there is a greater understanding of the serious problems of business and of the interdependence of men, of the real relationship that exists, and of the basic laws which operate unerringly in both the restraint and in the fulfillment of the desires and ambitions of men.

Many of the misunderstandings of the probelms of industry can be traced to the fact that some fair-minded men secure their information from those whose minds are warped by prejudice or controlled by ignorance, while those who do or should understand, and who have the responsibility of leadership, make no effort to counteract that lack of understanding.

On the other hand, misunderstandings can never be entirely eliminated while human nature, generally speaking, is as it is. They can, however, be largely reduced through the united effort of all those who, with unselfish purpose, are striving to fairly and equitably serve all interests concerned and to constantly acquire for themselves greater depths of human understanding.

It is my conviction, born of long contact with men, that the average man who works with his hands is honest, sound of heart, and wants to be fair in all things, and that he will be fair when he undertsands.

*President, American Rolling Mill Company, Middletown, Ohio.

It seems strange that in this day and age intelligent men have not learned that no one group can dominate another for more than a comparatively short time—too short to be profitable even to the one who dominates—and that successful domination of one group over another because of temporary advantage, prevents such accomplishment as will bring the increased reward that both sides are seeking.

No plan or scheme that is not reasonably fair to all parties concerned can possibly live long enough to be really profitable to any one, for the simple reason that enterprise cannot succeed in any degree worth while without the efficient co-operation of all groups engaged in it. No group of either so-called employers or employes will willingly submit to what they feel is an injustice longer than it takes them to find ways and means to upset or tear down the scheme imposed upon them.

As the days go by the world is learning that the strong cannot impose their selfish will upon the weak and get away with it for long enough to do them any real or lasting good.

So, if management wants to enjoy satisfactory working conditions, it must first secure the confidence and good-will of its working forces. These are things to be enjoyed only after they are deserved through giving men that measure of understanding of their mutual interests and responsibilities and that sort of a fair deal which sells them a company's policies. Moreover, any organization that does not in some reasonable degree secure the confidence and goodwill of its workers is suffering a tremendous loss, for it has become an industrial axiom that a man's best work is done only when his heart beats in rhythm with his head and hands.

Looking back over a short period of only 30 years, one can recall that a majority of the steel works and rolling mills of the country were each owned and operated by two or three men, often by only one man, who conducted the business, including the employment of and the negotiation with labor, as best suited his individual judgment. An employe in the iron and steel industry of those days—manager, clerk or mill worker—had no possible opportunity to acquire an interest in the business, and thus share proportionately in its success. Those were the day when the real boss who owned the mill employed a man big enough, strong enough, and fearless enough to BOSS every man in the employ of the company. Those were the days when might and not right held full sway. Labor troubles once started meant war, and the chance for each side to attempt to get even, for either actual or supposed grievances.

The change that has taken place in these 30 years is very marked—much more so than is appreciated by any one who has not faced the problem or studied the facts. I doubt that today there is a single rolling

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mill owned by the old type mill operator; he has become a figure in history. Today a large proportion of the mills of the country are controlled by corporations and managed by sound, industrial and humane policies, conceived and applied by men chosen by the stockholders. And this plan of selecting managers has brought about a marked change of attitude between management and men. It has given birth to the newer conception of the responsibilities of industry, and in place of the old dingy, stuffy, dirty, tumbledown mills usually located where fresh air could not be had, there has come the newer mill—light, well-ventilated, clean, orderly, and equipped with modern appliances for the protection of life and limb, and for the production of larger tonnages at a minimum cost.

And all this is a tribute to a growing recognition of the human element in industry, and that intangible "something" which is best described by the word spirit—that invisible part of human life which corresponds to the electrical current in a storage battery. As far as the mechanical side is concerned, the battery is completed before a wire is attached and the electric fluid injected, but in that condition it is absolutely worthless. However, just attach the contact wire, turn on the current, and, in due course, the battery has become a thing of life. The human body without spirit is like unto the uncharged battery; but give it spirit, which might be described as life in action, and you have turned a latent power into a constructive force.

Spirit is a force possessed by only such forms of life as have brains of such quality and in such quantity as to make energetic initiative possible. Company spirit, industrially speaking, is group spirit. It stands for loyalty to company, to fellow workers and for aggressive action and co-operation. It makes for human and industrial development in every direction—a happy condition that brings its own reward to the worker.

We must not forget that labor furnishes the constructive effort, the motive power, the ability to use skillfully the tools required. In fact, it must contribute all the human characteristics that make for efficient, continuous production and when such effort is properly directed and co-ordinated.

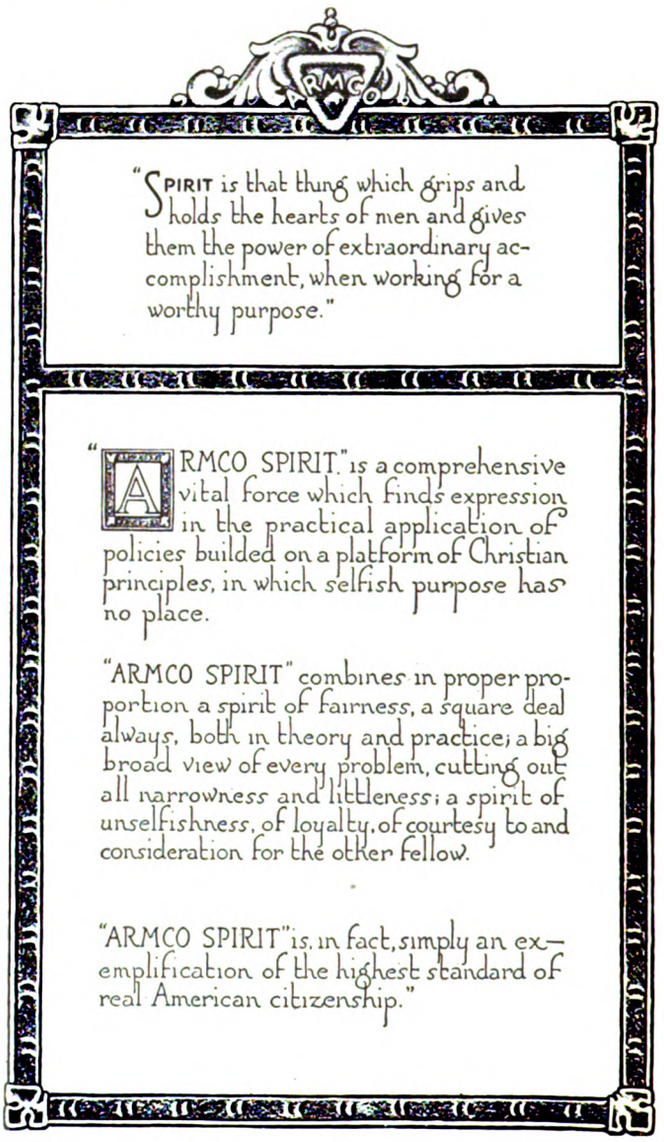
Co-operation is a word or phrase commonly used but often little understood. Too many have the idea that it is something coming to them instead of something going from them; that it is TO GET and not TO GIVE. Co-operation is not a man-made law. Everything in nature goes to prove that it is one of the strongest laws in life; and it seems strange that there should be so much selfishness in the human make-up when unselfishness and co-operation are so necessary to our very existence and success.

Nor do we need to wander far afield for proof of the efficacy of co-operation. There is no better illustration of perfect co-operation than that found in our own human system: The brain, the eyes, the ears, the heart, the lungs, the arms, the limbs—all work with rhythmical precision, each assisting and supporting the other automatically. You do not have to beg your lungs to breathe, your heart to beat, nor your limbs to run—you have only to wish it and you move. Again, if your good right arm is injured in any way, you do not find fault with it or think less of it because of that misfortune. No! You nurse it tenderly and save it from every possible strain or shock until it is fully recovered.

Co-operation, as visualized in human relations, is not merely a virtue. It should not be thought of as a virtue at all, but as something absolutely essential in all human accomplishment.

The average worker is not radical. He is fair and honest at heart, and will always respond to a square deal and a chance for development and promotion. He, however, wants policies announced, visualized in actual every day experiences and not merely in words.

With proper understanding between management and men, with all things affecting human life and progress, treated and handled as they can and should be in this enlightened age, every leader in industry and commerce can face the future in this great land of ever-increasing opportunity with optimism and confidence.



Above is reproduced the back cover of the Armco Bulletin for November, 1923. The bulletin, published monthly "in the interest of 'Armco Men,' under the direction of the Department of Personal Service," carries forth its frequent message of cheerful co-operation.

The page here reproduced is typical of its contents, and of the organization which sponsors it.

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Iron and Steel Review of 1923

Forecasts Based on "Decade Doubling" Rule Must Be Revised

By B. E. V. LUTY

IF there were such a thing as "normal" in steel, as to tonnage and prices, the review of a calendar year would naturally begin by stating how closely the year approached, or how far diverged from, the normal. But there is no normal in steel. Normal means something more than an average, but failing to have a normal, steel does not even have an average that can be taken to mean anything. Strike the arithmetical average of tonnage production or prices in steel for a period of years, and then add or drop a year at either end, and the average of the new group will probably be quite different.

It used to be thought that there was a normal rate of increase in the production of pig iron. Long range comparisons cannot deal with steel, because steel is too recent, having supplanted wrought iron as the chief rolled product only in the eighteen-nineties. The author has definite recollections on the subject, as the first editorial he ever wrote was on the decline in puddling. The editorial appeared in January, 1893, in the "American Manufacturer and Iron World," subsequently merged into the present Blast Furnace and Steel Plant, and showed as a result of a questionnaire that during 1892 the number of puddling furnaces in the Pittsburgh district had first decreased. There are no production statistics for that period separating rolled iron and rolled steel.

Pig iron production is more or less natural as showing the activity of the iron and steel industry as a whole. The much quoted rule of years ago was that pig iron production doubled every ten years. The rule was discovered, or at least given publicity, by the late Abram S. Hewitt, once Mayor of New York City, and himself an "ironmaster." The progression is not easily picked out by scrutiny of a table of production by calendar years, on account of wide fluctuations from year to year. The rule could be brought out nicely and plainly by taking decennial totals, but even then there are differences according to where the dividing line between the periods is placed.

Just now we are much disposed to divide history into three parts, before the war, during the war and after the war, and so the doubling rule may be considered by making the decades such that the last will end with 1913. Production of pig iron in the United States in gross tons has been as follows, in ten-year periods:

1824-33 - - - - -	1,400,000
1834-43 - - - - -	2,550,000
1844-53 - - - - -	5,750,000
1854-63 - - - - -	7,263,491
1864-73 - - - - -	15,980,823
1874-83 - - - - -	30,601,896
1884-93 - - - - -	68,100,326
1894-03 - - - - -	125,272,295
1904-13 - - - - -	243,955,657

This is probably the grouping of years that will make the closest showing for the rule. At a glance these appear to be only two break-downs, but there is a third, which is of the great importance. Apparently 1834-43 showed a failure, but as the decade following more than quadrupled the decade preceding, showing 5,750,000 tons instead of 5,600,000 tons this does not count against the rule. There was a break-down, not repaired, due to the very hard times that began with the panic of 1857. One may say that two or three years were lost forever, and then the doubling was resumed very plainly. The decade 1864-73 makes a basis by which the smallest departures are seen. Doubling its 16,000,000 tons slightly oversteps the next decade, but the following decade runs ahead of the quadrupling. Then the decade 1894 to 1903 makes the second breakdown but this has the important consequence that the decade 1904 to 1913 appears to show a doubling, by the immediate comparison, but it does not carry out the long range comparison.

In other words, at the outbreak of the World War the production of pig iron in the United States had gotten to the point where it could no longer carry out the geometrical progression. That is inevitable in any such case, whether coal mining or automobile production or what-not.

Geometric progressions have to stop or eventually everybody would have to be mining coal or making automobiles or producing pig iron. In the long run an industry can do no more than grow as the population grows and as methods are improved whereby a given amount of work produces more.

In such a geometrical progression, one decade must equal the total of all preceding time. This only fell five per cent short of working out in pig iron, thus:

1824 to 1903 - -	256,918,931
1904 to 1913 - -	243,955,657

Even with the great stimulus of the war demand, the following decade, just ended, has failed signally to approach the tonnage the rule would dictate. By the basis just used, 16,000,000 tons for 1864 to 1873, there should be 512,000,000 tons for 1914 to 1923, while doubling the decade 1904 to 1913 would make 488,000,000 tons. The actual production has been 322,000,000 tons, 37 per cent short of the one and 34 per cent short of the other.

Post War Conditions.

The opportunist may try to blame this on the war, but during the war most men thought otherwise. They believed the war was creating a great extra demand for iron and steel, that normal demand was piling up and that after the war this normal demand would be released, whereby all told there would be greater production in the combined war and post-war periods than would have occurred had there been no war.

The more practical view is to take it that the rule of doubling broke down some time ago and that we must judge things afresh, relating one year to its neighbors rather than to the distant past.

We are simply in a post-war period, but what does a post-war period mean? Some people thought it meant a period of great prosperity, in which everyone would get along unprecedently well. That is, because

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a great many workers had been killed or disabled and much wealth had been destroyed we should then all have more goods—obviously absurd. Others said there would be a great industrial depression, in which we should "pay" for the war—equally absurd for you can't pay by being idle.

One thing a post-war period does mean is a search by a cut and dry method for a substantial basis. Price standards, for comparison, had been lost. Naturally there would be swings, wide at first and tapering off. Iron and steel prices declined slightly after the war and then in 1920 advanced tremendously. The following year they dropped to a lower level relative to actual cost of production than had ever been seen before. The big vibration caused by the war is dying out. The pendulum swings less and less.

Tonnage in 1923.

For comparisons with recent years steel rather than pig iron may be used. According to the basis selected the steel production of 1923 was good, bad or indifferent. The production of ingots was between 43,000,000 and 43,500,000 tons, and may be taken at 43,000,000 tons.

The year was a bad one in that at least as often as not in the past the production of steel in a year has made a new record, whereas 1923 did not altogether equal the record made six years earlier, with 43,619,200 tons in 1917.

It was an indifferent year on the basis that production was only about 82 per cent of rated capacity, which may be taken at 52,500,000 tons, while before the war it was the common view that steel demand had to engage at least 85 per cent of the capacity for prices to be at all satisfactory.

It was a very good year on the basis that the production was 35 per cent above the average of the four preceding years. If the first four years after the war do not furnish any basis for comparison, what is the use in trying to make comparisons?

The productive capacity is merely an accident of the war. Much of the war-time construction was predicated upon its paying for itself before the war should end. Afterwards, with a practical cessation of new construction, the country could grow up to the higher level. It may be well to insert here a table showing the actual production of steel ingots, in gross tons:

1912	30,284,682
1913	30,280,130
1914	22,819,784
1915	31,284,212
1916	41,401,917
1917	43,619,200
1918	43,051,022
1919	33,694,795
1920	40,881,392
1921	19,224,084
1922	34,568,418
1923	43,000,000

In passing, it may be noted that while steel ingots did not make a new record in 1923, pig iron did, the 40,000,000 tons produced passing the record of 39,434,797 tons produced in 1916. The point is merely of statistical interest.

The Question of Normal.

As has been said, there is no normal in steel, that is, no normal derived by the usual process of making a graph or striking an arithmetical average. The question can be approached from another and more practical side. Instead of using the word "normal," take the concept of "natural". The consumption of some small and unusual article may fluctuate very widely, but steel is so great a part of our industrial life that it cannot vary a great deal relatively. Nearly all our industrial activity involves steel.

The natural viewpoint as to steel is simply this, that the country is a great industrial machine and according as it functions, so steel is produced and consumed. There are so many persons gainfully employed, the number increasing at the rate of something like 10 per cent per decade. The proportion of workers engaged more or less directly with steel may vary somewhat. The proportion engaged in operating railroad trains may decrease and the proportion wearing out automobiles may increase. Men may cease making wooden furniture and make steel furniture instead. Then there may be improvements in practice instead. Then there may be improvements in practice whereby an agricultural implement factory employing a certain number of men may turn out more implements and thus use more steel. Finally there is the matter of how busy the country is. All the workers may be at work or some may be idle.

The consumption of steel in any given year may therefore be regarded as represented by the continued product of the following factors:

Total number of workers (growing population).
Proportion engaged in working up steel (new uses).
Efficiency of methods in consuming steel.
Proportion of general business activity.

The writer believes that if precise and correct values could be assigned to each of these four factors the product would stand in substantially exact relation to the consumption of steel at one time or another. Production would not do for short range comparisons. For instance, in 1920 the country stocked up with steel, machinery, implements, etc., and had to liquidate in 1921, getting the manufacturers of steel into final hands.

Let us compare 1912 and 1913 with 1923. Each year had five or ten per cent of idleness or slack times, while 1923 had no idleness. With similar business activity those two pre-war years would have shown about 32,000,000 tons of ingots, and the 43,000,000 tons in 1923 would be 35 per cent increase. Of this, 12 or 13 per cent is assignable to increase in population, which would make 36,000,000 tons, leaving 20 per cent to be accounted for by other factors. Harder work will not account for anything, since men are not working harder. New uses can hardly be counted. We have the automobile and other things, but on the other hand there is some diversion of workers. A large proportion of the workers have been engaged in road building and dwelling house construction, which use relatively little steel, and a smaller proportion in building factories, skyscraper hotel and office buildings and bridges, which use much steel relative to man-power employed. The 20 per cent increase in steel, beyond the 12 or 13 per cent assignable to increase in population, would probably be found chiefly in improvements in methods whereby the same amount of effort will consume or put into use more steel.

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Applied to the Future.

We may use these factors in looking into the future. Population will probably increase something like 10 per cent per decade. Employment will probably shift somewhat from the alignment of 1923, less road building and dwelling house construction, more factory, power plant, electric transmission and railroad development. Efficiency will increase. These three factors will each make for more steel consumption. The fourth, general activity, can only move downward. There was full employment in 1923. There cannot be more than that and there can be less.

For 1924 as compared with 1923 the first three factors can effect little increase, in so short a time. The fourth could effect considerable decrease but there is no definite indication at this time that it will. Any variation, however, will necessarily be downward.

Finally for the close range comparison a correction must be made. The year 1923 was entered with consumers and distributers practically bare of stocks, which were certainly below normal. The year ends with stocks presumably about normal, though not excessive. It is impossible to make even an intelligent guess, but to put the matter into figures this can be said, that the four post-war years, 1919 to 1922, showed an average ingot production of 32,000,000 tons a year, while with 43,000,000 tons in 1923 the five post-war years make an average of 34,200,000 tons a year, whereby 1924 can be 10 per cent under 1923 and yet 13 per cent above the average of its five predecessors.

Prices and Profits.

The surprising thing about the steel market in the second half of 1923 was its failure to bear out predictions of price declines. When the peak prices of 1920 began to yield there was a continuous decline until early in March, 1922, covering say 18 months. Then prices advanced until late in 1922, when the advance halted, to be resumed in January, 1923. The last advances occurred late in April. Then predictions began to appear that prices would soon begin to fall. As the months passed the predictions became more numerous, but prices did not decline. Demand did not keep up in full, but it held out better than had been expected. It was not a matter of relation between demand and productive capacity, for throughout the price advancing period the mills were operating at under capacity. Production costs had increased by wage advances and other factors, and believing that prices were only fair, mills were resolved to hold them, particularly as they had had the experience of the previous 18-month decline, to a level below cost, and did not want a market disturbance to start. The year 1924 may see some occasional yielding in prices, here or there, but with the fair demand that seems now to be fully promised there is not likely to be much change.

Why Fear 1924?

The general accepted conviction that a presidential year means poor business is characterized as "false and foolish" by Congressman Martin L. Davey of Ohio, in an article on "Why Fear a Presidential Year"? in the current number of The Nation's Business.

Mr. Davey, who writes as a business man rather than a member of Congress, declares that when business was below normal in past presidential years this condition was due to some underlying economic cause and not to the fact that a president was to be elected. Since 1880, according to Congressman Davey, there have been five lean presidential years and five fat years. The last presidential year, 1920, had six months of good and six months of poor business.

"The most serious recent depression," he writes, "was early in 1921. It was estimated that there were 5,000,000 people out of work. There are probably not less than 25,000,000 people in this country who have regular employment of one kind or another; so this worst period of business depression saw not more than 20 per cent of the people out of work, thus largely stripped of their buying power. It might be argued, then, that the difference between peak prosperity and this more serious depression was not more than 20 per cent.

"By the same process of reasoning, it would seem that the difference between ordinary prosperity and ordinary depression is not over 10 or 15 per cent.

"The demands of the American people, even in periods of depression, are so enormous that they stagger the imagination. What we call prosperity would appear to be the extra 10 or 16 per cent demand above that of a period of depression.

In reviewing the business history of presidential years during the last half century, Congressman Davey writes: "Business was bad in the last half of 1920—yes, that was a presidential year — but business became worse and worse after the election and reached its lowest level about the middle of 1921. There was a very slow recovery from that time until the spring of 1922. Doesn't this seem, then, that is was not the election of 1920 that caused bad business, because conditions became worse after the election? That depression was due to underlying economic causes.

"The year 1916 was also a presidential one. The chart shows that in that year business was between 10 and 20 per cent above normal. Why did we have prosperity in 1916? Simply because the demands of the war were so insistent and widespread that even a blind man could see it. Everybody forgot about the effect on business of a presidential year, and we prospered during that year because the economic conditions were right.

"We had an election in 1912. In the preceding year business was a little below normal, but in 1912 business ran from 5 to 10 per cent above normal.

"Go back then to 1908, which was also a presidential year. In the fall of 1907 we had, as most of us recall, bad times which continued until about the middle of 1908, when business started on the upgrade.

"There had been depression in the latter half of 1903, and then followed the election year of 1904, during which business was generally on the up-grade, although there was a slight reaction about the middle of 1904.

"Then we came to the presidential year of 1900. The trend of business in 1900 apparently proceeded without the slightest regard for the election.

"In 1896 the business interests of the country were more or less alarmed by the free silver campaign and this probably had some direct bearing upon the volume of business, because there was a slight upward tendency which followed immediately after the election of that year.

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Blast Furnace Progress

1923 Saw a Return Toward Normal Operating Conditions —Much Research Undertaken

By J. A. MOHR*

THE year 1923 saw developments of much interest in blast furnace operation and practice. In output of pig iron it exceeded the high level reached during the war period. The low ebb of production in the middle of 1921 was followed by a sharp increase in 1922, which continued in 1923, reaching its highest point in May, since which time there has been a steady decline in production, a forerunner perhaps of another wave of depression, with its consequent keen competition and stringent economies.

Furnace operation has been on a more normal plane than at any time since the war; coke and car shortages of past years were dominant; labor, while scarce, was not acute as in 1922. The effect of more settled conditions was reflected also in the generally better quality of raw materials, and altogether much has been done to smooth out the irregularities that have confronted the operator for several years.

Economies of fuel and labor have held the front to a very marked degree. The increasing demand for power from the blast furnace plant caused by electrification of its adjacent steel plant, or the realization of the economy of the sale of electric power as a by-product has been the means of remodeling, and in many cases replacing old and wasteful equipment with modern economical machinery, to increase the by-pro-

*Superintendent Carrie Furnaces, Carnegie Steel Company, Rankin, Pa.

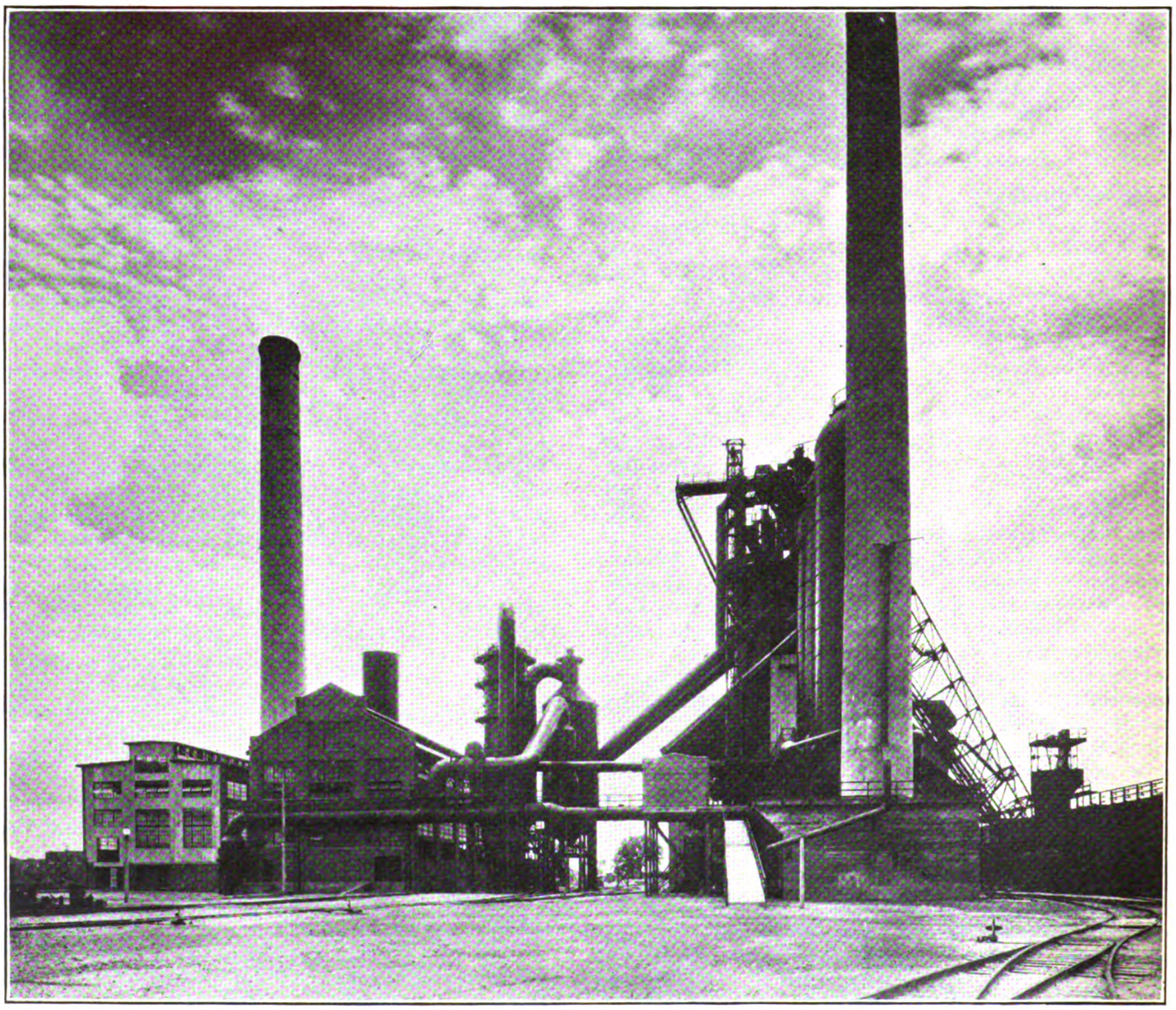

FIG. 1—*A remarkable view of world record furnace of Trumbull Cliffs Iron Company at Warren, Ohio. This furnace produced* 1,011 *tons of iron in a single day (March,* 1923), *and averaged over* 800 *tons per day for the month of November, during which period straight ore was charged.*

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duct power output. With the increase in cost of fuel that has obtained in past few years, this development of fuel economy will be of ever increasing intensity, and demands the attention of every operator more and more.

Mr. H. C. Siebert, combustion engineer of Bethlehem Steel Company, in a recent paper before the Iron & Steel Electrical Engineers clearly points out the possibilities of power production at the blast furnace. quoting from his paper:

Relation of the Blast Furnace to Fuel Economy in a Steel Plant.

In a modern steel plant the blast furnace is the most important link in the chain of three primary units. It is the largest consumer of fuel, but also the largest producer of a valuable by-product — blast furnace gas — in which is present 50 per cent and more of the heat value of the coke entering the furnace. The bearing which the blast furnace has on fuel economy in general may be realized from the fact that in a good business year the production of pig iron in this country amounts to 37 million gross tons. With a fuel rate of 2100 lbs. per gross ton iron the coke required is 35 million gross tons, and the coal necessary to produce this coke is about 50 million gross tons.

Taking a net heat value of 12800 Btu. per lb. coke and 50 per cent of this heat as available in the form of blast furnace gas we get on the basis of 13,000 Btu. per lb. coal, the fuel equivalent of 17.3 million tons coal per year. Assuming a high figure for the fuel required for heating the blast (one third the remainder or 11.5 million tons is available for general power purposes. This coal will generate nearly one-half of the electric power produced in this country, on the basis of present steam power plant requirement of coal.

From the preceding and from the following data it will be seen that the blast furnace is a huge gas producer of high efficiency. The economy which may be derived from the use of blast furnace gas depends upon the type of equipment in the plant. The factor of primary influence in this connection is the hot blast stove, which may require 15 per cent or 50 per cent of the total gas, depending upon the amount of its heating surface, the type of burner equipment, the means of control, the fineness of gas cleaning, and on other details. Another factor of importance is the type of blowing and other power equipment. Thus more power and more surplus gas will be available for the steel plant if gas engines be used for power and for blowing purposes.

As in the operation of the by-product coke oven, so in the operation of the blast furnace, the process of combustion must be carefully supervised and controlled. Every phase of the operation is checked qualitatively and quantitatively. Thus chemical analyses is made of the materials entering and leaving the furnace. Record is kept of the air blown of the blast temperature and pressure, of the weight of material charged, etc., and especial attention is given to the quality and quantity of the fuel charged.

The chief requirement of the blast furnace is that it produce iron of good quality and quantity with economy in coke. In its operation fuel (coke) plays a very important part as the entire process of iron and steel manufacture is influenced perhaps more by the character of the fuel used than by any other factor connected with the furnace burden.

Quality of the materials entering into the furnace burned as well as the distribution of those materials influence the operation of the steel plant as a whole. Thus poor coal may cause poor coke which may cause an irregular working of the furnace. Thus the quality and quantity of product will be influenced unfavorably and fuel economy of the furnace and of the other departments will be decreased. Other materials of the burden or a poor distribution of the materials may under certain conditions lead to similar consequences.

The detail of blast furnace construction is so well known that it need not be considered here. It will suffice to state that present tendency in construction is in the direction of large hearths, the claim for which is greater output in iron and a greater fuel economy. So far as the writer is aware the largest hearth in use at present on a furnace smelting Mesaba ores is 20 ft. 6 in. diameter. The output in iron consistently amounts to 600 tons and more per day.

The average daily production of a modern blast furnace is less than the figure given above, a good daily average being 450 to 500 tons.

Mr. K. Huessner, of the American Heat Economy Bureau, Pittsburgh, follows with an interesting discussion.

The part of Mr. Siebert's extremely valuable paper which interests me most is the amount of power calculated by Mr. Siebert as obtainable from a 500-ton blast furnace using up-to-date steam equipment and maintaining a stove efficiency of 80 per cent. This amount is given in Table No. XVII as 8,800 k.w. per hour. This amount is vastly in excess of what is at present obtainable even at the best regulated plants. At the same time, I quite agree with Mr. Siebert's calculations, with the only exception that I think Mr. Siebert ought to have made some allowance for gas leakage. Even in the best plants, a certain amount of leakage cannot be avoided, quite apart from losses through slips, etc.

I believe that, if the gas orifices supplying stoves and boilers are properly apportioned, the top pressure can be kept comparatively low, in any case lower than the top pressures which are now generally being held at most of the up-to-date plants which operate on high blast pressures. But, even assuming the top pressure never exceeds 8-in., except in the case of slips, I think an allowance of 5 per cent of the total gas for leakage should be made. By doing so, the available heat for power production given in Scheme 2, Table XVII, at 171,000,000 Btu. would be reduced to 157,000,000 Btu. and the hourly rate of current production from 8800 to approximately 8,100 k.w. Deducting from this amount the auxiliary load of approximately 1,800 k.w., would leave a surplus current production, for which the furnace would receive credit, of 6,300 k.w. per hour. At a value of only ½c per k.w., this would mean an hourly credit of $31.50, or $1.50 per ton of iron.

That such results can eventually be obtained, can hardly be disputed, but it might be worth while to investigate the difficulties which are in the way. The main difficulty of keeping perfect combustion at all times by means of automatic control, irrespective of pressure conditions, has been solved. I am giving hereafter two tables of combustion analyses made un-

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Date 1923 Feb.	No. 1 Stove CO_2	O_2	CO	No. 2 Stove CO_2	O_2	CO	No. 3 Stove CO_2	O_2	CO	No. 4 Stove CO_2	O_2	CO
1	25.7	.3	.0	24.7	.5	.0	21.0	2.0	.0	24.5	.7	.0
										24.5	.5	.0
10	25.2	.2	.0	24.4	.7	.0	24.0	.9	.0	23.0	1.8	.0
							26.0	.2	.0	25.6	.2	.0
										25.8	.2	.0
14	24.3	1.5	.0				25.0	1.0	.0	24.5	1.0	.0
	24.0	2.0	.0				24.0	1.6	.0	24.0	1.0	.0
										26.5	.0	.3
15	26.7	.5	.0	23.9	1.9	.0	25.2	.9	.0	23.0	2.5	.0
	24.0	1.3	.0	24.6	1.2	.0	26.3	.6	.0			
	25.3	1.0	.0				25.8	1.0	.0			
16	24.8	1.0	.0	23.0	2.2	.0	25.0	1.0	.0			
	24.0	2.0	.0									
17	24.0	1.0	.0	25.1	1.0	.0	23.8	1.8	.0	25.3	1.4	.0
	23.7	1.5	.0									
	24.0	1.3	.0									
	24.0	1.4	.0									
	25.8	.8	.0									
20				25.5	1.0	.0	24.8	1.0	.0	26.8	.2	.0
				24.8	.7	.0				26.0	.6	.0
								CO_2		O_2		CO
Average of 45 analyses								24.71		1.05		.007

der ordinary operating conditions and not with any view to running a test."

Economy of labor is of as much importance, and much has been done in the past year to reduce labor requirements to the lowest degree. The acute labor shortage of the past two years might be termed a blessing in disguise to the operator. It served well in showing where men could be eliminated who were before thought necessary, and where marked economies could be gained in labor by slight improvements or modifications of existing equipment and methods.

The most important development in labor conditions during the year was the successful institution of the eight-hour day in the blast furnace and steel plants. Starting in August, the change was made with startling speed and smoothness in all of the large blast furnace and steel plants. Most smaller plants have followed suit, and in a few more months the 12-hour turn will have been practically eliminated from the industry. It is not possible as yet to get a full understanding of the effect this development will have on the labor conditions of the industry, but, based on the short time it has been in effect, the following conclusions seem assured: First: It will result in a better quality of men, attracted by shorter hours and better pay. Secondly: It will be the means of raising the standard of labor in the industry relative to that of other industries. Third: Men will lose less time from work, due to a turn requiring less endurance than formerly, and also due to their having more time per turn to themselves to take care of other interests. Fourth: Increased efficiency of the men—they can be expected to do more work per hour for eight hours than was possible for twelve hours. Most operators, at the institution of the eight hour day, took advantage of this obvious possibility to reduce the number of men per eight hour turn as compared with the number required per twelve hour turn. Fifth: Economizing of labor will be made still more intensive, due to the demand the eight hour day has placed upon an already scant labor supply.

Much progress has been made during the year in scientific research of the factors affecting the furnace operation.

In this connection the work of P. H. Royster, assistant metallurgist, Bureau of Mines; T. L. Joseph, assistant metallurgist, Bureau of Mines; S. P. Kinney, assistant metallurgist chemist, Bureau of Mines, issued in Report of Investigations, Series No. 2524, is worthy of comment.*

An investigation of the production of iron in the blast furnace is obviously not an easy subject for research. Enough is known of the mechanical, thermal and chemical conditions existing inside the furnace to say certainly that they are complicated. Furnace operators have found that the process is sensitive to a number of known and to many unknown operating conditions. In order to form any conclusions of value, it seems necessary to collect a large amount of data taken with considerable care and accuracy. These facts make a blast furnace research difficult but not impossible. The most serious obstacle in attacking the problem and operation of the blast furnace to use the method of "trial and error," which has proved valuable in so many other industrial problems. The variables are so interrelated and are so dependent one on the other that the number of experimental combinations to be tried is enormous. There are certainly not less than 20 factors in furnace operation and design that are known to influence the results. This is apparent if it is remembered that a phrase like "size and shape of the furnace" includes height of the furnace, height, diameter and angle of the bosh, inwall batter stockline diameter, and furnace volume; and that a phrase like "chemical and physical properties of the fuels charged" includes size and shape of the lumps, density, porosity and strength of the coke, in addition to its chemical analysis. Let us suppose that we need choose for each of 20 factors one of two values, for example, suppose we must say only that the furnace shall be "tall" or "short," that the bosh angle shall be "flat" or "steep," that the ore shall be "coarse" or "fine," or that the blast has to be "hot" or "cold," the number of resulting combinations is more than 1,000,000. In putting 20 pennies on the table, either heads up or tails up, the number of permutations possible is the twentieth power of two, slightly more than one million. It is obvious, therefore, that some sort of mathematical relationship, a set of rules of thumb, laws, curves or the like are needed. Whether the relationships, curves or formulas are derived from experiment, from theory, or from mere guess-work, makes no difference provided they agree with the known facts. If they do not agree with known facts, they are worthless no matter what their origin or how weighty the "authority" vouching for them. Few such relationships have appeared in blast-furnace literature, and it may be doubted whether such formulas can be discovered.

The Department of the Interior has been investigating the blast furnace process since 1916. The conduct of this research, carried out by the metallurgical division of the Bureau of Mines, has not been simple. None of the possible methods of investigation has appeared promising. Three kinds of study have been tried. It has been found convenient to label these;

*The report of this investigation begins in this issue of the Blast Furnace and Steel Plant.

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DATA ON GAS AND AIR OF BLAST FURNACES PRODUCING IRON AND ALLOY FROM MESABA AND FOREIGN ORES AND FROM MIXTURES OF THESE ORES.

DATA BY		MATHESIUS	MACCOUN	AUTHOR					
ORES USED		MESABA				DOMESTIC AND FOREIGN			
PRODUCT		IRON						FERRO MANGANESE	
TONS PRODUCT PER DAY		577	406	439	450	330	384	118	101
LBS. COKE PER TON PRODUCT		1682	1927	2270	1917	2240	2560	4860	5660
" COAL " " "								265	173
" STONE " " "		795	1498	1070	947	1097	1698	1810	1420
" CARBON(TOTAL) PER TON PRODUCT		1571	1773	2018	1743	1955	2384	4597	5160
" " IN GAS " " "		1470	1647	1910	1642	1860	2283	4494	5059
GAS ANALYSIS % BY VOLUME	CO_2	14.9	16.3	11.1	10.8	11.7	7.5	5.9	5.3
	CO	23.5	22.7	26.7	27.9	26.5	32.2	31.6	32.7
	CH_4	0.2		0.2	0.2	0.2	0.2	0.8	1.0
	$CO_2 + CO + CH_4$	38.6	39.0	38.0	38.9	38.4	39.9	38.3	39.0
	H_2	4.1	2.0	3.8	3.5	3.5	2.2	3.6	2.5
	N_2	57.3	59.0	58.2	57.6	58.1	57.9	58.1	58.5
TEMP. OF GAS AT TOP OF FCE°-F		325	324	350	365	390	400	700	700
NET B.T.U. PER CU. FT. GAS		89	82	98	101	97	111	119	121
SENSIBLE HEAT B.T.U. PER CU. FT. GAS		5	5	6	6	7	7	13	13
TOTAL B.T.U. " " " "		94	87	104	107	104	118	132	134
LBS. CARBON PER CU. FT. GAS		.0122	.0123	.0120	.0123	.0121	.0126	.0121	.0123
THOUSAND CU. FT. GAS PER TON PROD.		120.5	133.8	159	134	153.6	181	372	412
CU. FT. GAS PER LB. COKE AND COKE EQUIVALENT		71.6	69.6	70.1	70	68.6	70.7	73.1	70.8
THOUSAND CU. FT. AIR PER TON PROD.		87.8	100	117.1	98	112.8	132.9	275	305
CU. FT. AIR PER LB. COKE		52.3	51.9	51.7	51.2	50.5	52	54	52.4
B.T.U. PER LB. COKE		13,000	12,450	12,800					
B.T.U. IN DRY GAS PER LB. COKE	CALORIFIC VALUE	6400	5700	6880	7050	6650	7850	8700	8560
	TOTAL HEAT VALUE	6750	6050	7160	7470	7130	8350	9660	9500
HEAT IN DRY GAS IN % OF HEAT IN COKE CHARGED INTO FCE.	CALORIFIC VALUE	49.2	45.8	53.7	55	51.9	61.2	68	66.9
	TOTAL HEAT VALUE	51.9	48.7	56	58.4	55.7	65.1	75.5	74.2

NOTE:-

TEST BY MACCOUN WAS MADE ON FURNACE OPERATED ON DRY BLAST.
ALL OTHER DATA REFERS TO FURNACES RUN ON NATURAL BLAST.
GAS AND AIR VOLUME IS REFERRED TO THE STANDARD OF 62° F AND 30" BAROMETER.

WEIGHT OF CARBON PER CU. FT. GAS = $(CO_2 + CO + CH_4) \times 0.0316$

CU. FT. GAS PER TON IRON = $\frac{\text{LBS. CARBON IN GAS PER TON}}{\text{LBS. CARBON PER CU. FT. GAS}}$

CU. FT. AIR PER TON IRON = CU. FT. GAS PER TON $\times \frac{N_2 \text{ IN GAS}}{N_2 \text{ IN AIR}}$

FIG. 2—*A very convenient table of blast furnace factors in ready reference form.* *Courtesy H. C. Siebert.*

plant observations, laboratory research, and experimental blast-furnace operation.

Since 1919 the Bureau of Mines has constructed and blown in 35 experimental furnaces at its North Central Experiment Station, Minneapolis. The primary object in designing and operating these furnaces was to establish working principles to aid the Bureau in its own experimental work. Enough progress has been made, however, to say that the experimental blast furnace is now an established and proven piece of research equipment.

During the past year the results obtained in the operation of the experimental furnace at Minneapolis have been so far-reaching that the aspect of the problem has been considerably changed. Unless the bureau is able to prove that its data are incorrect—and it is trying to do this—the whole trend of blast furnace research will have to be altered. The experimental furnace is less than one-quarter of the standard height (75 to 100 feet) adopted in England 50 years ago. All the furnaces built since the "metallurgical revolution of 1870" have copied the height used at that time. In the following half century commercial practice, industrial development and technical research have changed nearly every other detail of design, of construction and of operation. Blowing equipment, stoves, method of charging materials and means for disposing of products have been improved to such extent that the goal of quantity production has been attained. Tonnages from furnace units have been increased five-fold and at the same time the actual amount of labor employed has been reduced. Progress during this past 50 years of iron-making has been great, but it has been mechanical and industrial progress, rather than metal-

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lurgical. The modern American blast furnace with its stoves costs less than one-fifth of the total cost of the furnace plant.* It is as cheap to tear down and rebuild five furnaces as it is to modernize the equipment of one. Today many furnaces are rather inefficient in their blowing, preheating, gas and material handling equipment. Blast furnace engineers, however, are available with the knowledge, skill and experience necessary to bring the equipment of these plants to such a degree of efficiency that the fundamental metallurgy of the process will again become the weakest link in the chain. The more recent results of the bureau's research, therefore, are of particular interest at this time."

Extensive efforts are being made by investigators to find the factors affecting furnace production, coke consumption, life of lining and other phases of operation. The properties of coke as affecting the blast furnace have been extensively investigated. Koppers, the U. S. Bureau of Mines (as noted previously), and others have been actively interested in this work. Analyses of the different properties of coke, such as hardness, porosity, cell structure, specific gravity, composition, etc., are being made in an effort to determine what effect these factors have upon the combustibility of coke and its use in the furnace. Nothing definite has yet been accomplished, but this development is of wide interest and large value to the furnace operators, who have contended for years that much coke being made for blast furnace use does not fulfill the requirements of modern practice. Possibilities of reducing the coke ash and sulphur have been brought out during the past year, having as their object the reduction of fuel consumption, sulphur elimination, and the use of leaner and more silicious ores in the burden. But such efforts have not yet been introduced into actual practice, at least not to any great extent.

The resumption of ore production at the famous Iron Mountain mines in Missouri, and the reduction of this ore by coke produced in by-product ovens from 100 per cent Illinois coal at the plants of the National Enameling & Stamping Company, Granite City, Ill., was described in the October Blast Furnace & Steel Plant.

Development of furnace lines for increased production seems to be closely approaching its upper limits for the present materials used in the furnace. No attempt has been made during the present year to exceed the 20 ft. 9 in. hearth furnace first built in 1918. However, the large hearth furnace to its present limits has been a marked success and stands out as the greatest step in modern practice. Present attempts to increase production are being made in remodeling old furnaces to larger sizes, in enriching the burden with additions of scrap, and in remodeling the blowing, stove and over auxiliary equipment of the furnace so that the full demand of the larger furnaces in wind, blast temperature, filling, and otherwise, can be met.

Investigation of the qualities of fire brick and causes of failure of furnace linings has been made prominent by the results obtained by Nesbitt and Bell in the past year in their efforts to solve this problem. These investigators have succeeded in disintegrating fire clay brick by exposing it to the action of both pure CO gas and blast furnace gas at temperatures of about 450 deg. C. Disintegration of the brick was found to have been caused by carbon deposition around iron oxided deposits, the swelling resulting from this action disintegrating the brick. The authors point out that either the use of a pure clay or of a properly weathered and selected clay is necessary for the production of a brick capable of withstanding this action. This work has been of large value to the blast furnace, and, while much work is yet to be done, a large step has been made in the development of better quality in furnace linings.

The proper cleaning of blast furnace gas has long held the attention of the furnace operator, and the present year has marked the installation of at least one type of cleaner which had not heretofore been used in this country for cleaning blast furnace gas. The arguments pro and con regarding wet washing and dry cleaning have been many, but actual development of either type has not advanced during the year.

One factor, whose effect on furnace operation, production, size, and auxiliaries could readily be of the most far reaching development that ever occurred in the blast furnace plant, the oxygen enrichment of air in the blast, has been the subject of serious investigation. While no method has yet been devised of producing sufficient quantities of oxygen cheap enough to allow of its economical use in the blast furnace, still even the possibilities of this being accomplished have aroused wide interest.

*Iron-making Economies Developed in 1922, F. H. Wilcox. Iron Age,, Jan. 4, 1923, p. 84.

The ninth edition of the Shape Book, published by Carnegie Steel Company, is now off the press and available to users of steel. The new edition is the result of a thorough check and revision of all the sections rolled by Carnegie Steel Company on its shape, rail, bar and plate mills, and while no important changes have been made in the regular sizes of structural and bar mill sizes of beams, channels, angles, tees and zees, a number of changes have been made in the large number of special sections rolled by that company, such as concrete reinforcement bars, window and casement sections, automobile rim sections and other miscellaneous bar mill sections; certain rails and splice bar sections, which have become obsolete since the issue of the preceding eighth edition, have been eliminated in the present issue.

A pamphlet entitled "Trade Standards Adopted by the Compressed Air Society" has just been published, embodying the result of extended study and research on the part of the executives and engineers associated with the members of that organization. It embraces the nomenclature and terminology relating to air compressors and their operations; a history of the development of speeds of air compressors an explanation of capacities and pressures; instructions for the installation and care of air compressors with illustrations of devices suggested for cleaning the intake air; recommendation for the lubrication of air compressing machines and the cleaning of air receiver piping; a description of the low pressure nozzle test recommended by the Society, and a partial list of applications of compressed air. The Compressed Air Society publishes this pamphlet with the belief that there is a need for such an authoritative work of reference and that compressed air engineers and users as well as manufacturers of air compressors will appreciate this step toward the establishment of definite trade standards in the industry. Copies may be had from the members or by addressing the secretary of the society, C. H. Rohrbach, 50 Church Street, New York.

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Review of Iron and Steel Literature for 1923

A Classified List of the More Important Books, Serials and Trade Publications During the Year; with a Few of Earlier Date, Not Previously Announced

By E. H. McCLELLAND*

NOWHERE have we seen recent progress in ferrous metallurgy more concisely outlined than in the preface to the third edition of Bradley Stoughton's "Metallurgy of Iron and Steel." In explaining the necessity for entirely rewriting certain parts of this well known text-book, the author enumerates some of the more important developments during recent years: The blast-furnace has become mainly a producer of molten metal instead of cast pig-iron; improved design has increased production; scientific control is relied upon, and satisfactory results are produced even with poorer ores and fuels. The automotive industries have been one factor in stimulating the large-tonnage production of high-quality steel. The technique of open-hearth operation has been improved; the Bessemer converter now functions mainly as an accessory to the basic open-hearth furnace, and it is pretty generally recognized that acid open-hearth steel is superior to basic. Electrometallurgy has made rapid advances; metallography is widely recognized as essential in supplementing chemical and mechanical testing; more attention is given to hardness testing and dynamic testing; examination by means of X-rays or magnetic analysis is establishing itself; and the development of alloy steels has been rapid.

This rapid progress is a continuous challenge to the technical man. Since practice is always somewhat in advance of published information, the specialist may profit little from the literature concerned with his own special field of endeavor; but very few men have the time or the facilities for obtaining adequate first-hand knowledge regarding the entire range of steel technology, and thus, for most students of the subject, the printed word constitutes the best available medium for keeping in touch with new developments.

The following review (which forms the seventh annual review prepared for the January issue of The Blast Furnace and Steel Plant) is confined to separately published works appearing in 1923, or too late in 1922 to be included in last year's review.

Where possible, the books have been personally examined by the compiler of this review. Certain publications, however, were not available and the only information regarding them was in reviews in technical journals, which in many cases failed to give adequate information. Some of the entries are therefore incomplete, and some are perhaps inaccurate.

GENERAL

Geology, Ores.

Crowell & Murray. Iron Ores of Lake Superior. Ed. 5, revised. 332 pp. 1923. Penton Publishing Co., Cleveland, O. $5.

Valuable information, including history, geology, mineralogy, exploration and mining, classification and sampling, methods of analysis, valuation, dock equipment, and description of individual mines and ores.

England—Imperial Mineral Resources Bureau. Iron Ore; Summary of Information as to Present and Prospective Iron-Ore Supplies of the World. H. M. Stationery Office, London.

Pt. 7. Foreign America. 136 pp. 1922. 4 sh.
Pt. 8. Foreign Asia. 79 pp. 1922. 2 sh. 6 d.
Accompanied by maps showing deposits.

Jack, Robert Lockhart. Iron Ore Resources of South Australia. 71 pp. 1922. Government Printer, Adelaide. (Geological Survey of South Australia. Bulletin 9.)

Louis, Henry. Mineral Valuation. 281 pp. 1923. Charles Griffin & Co., Ltd., London. 15 sh.
Rather elementary work on general principles. Includes examples from coal and iron properties.

Murakami, Hanzo. Geology of the An-Shan Iron Mine District, South Manchuria. 53 pp. 1922. South Manchurian Railway.
"Will be welcomed by all who wish to know more of the geology of Asia."—*Economic Geology,* Dec. 1922.

Oglebay, Norton & Company. Lake Superior Iron Ores. 31 pp. 1923. The Company, Cleveland, O.
Analyses, 1923.

Pickands, Mather & Company. Cargo Analyses, Lake Superior Iron Ores. 19 pp. 1923. Cleveland, O.

Shedd, Solon, and others. Iron Ores, Fuels and Fluxes of Washington. 160 pp. 1922. (State of Washington—Department of Conservation and Development. Bulletin 27, Geological Series.)

Manufacture, Testing.

Barberot, A. Fabrication de l'acier au four Martin. 543 pp. 1923. J. B. Baillière et Fils, Paris. 40 fr.
Deals quite fully with design, construction, heating and operation of open-hearth furnaces. "Index bibliographique" comprises five (unnumbered) pages.

Belaiew, N. T. Crystallisation of Metals. 143 pp. 1922. University of London Press, Ltd., London. 7 sh. 6 d.
Lectures in advanced metallurgy, with considerable attention to ferrous metals.

Bethlehem Steel Company. Bethlehem Mayari Pig Iron; a Natural Nickel-Chromium Alloy Iron for Making High-Grade Castings. 103 pp. 1923. Bethlehem, Pa. $1. (Publication 26.)
Discusses applications, outlines proper foundry practice, and presents tests. Part of the book is prepared by Richard Moldenke.

Brayshaw, Shipley N. Verhinderung von Haerterissen in Werkzeugstahl. Translated by Hans von Jueptner. 129 pp. 1922. Arthur Felix, Leipsic. $1.
Translation of paper before Iron and Steel Institute.

Burnham, Thomas H. Special Steels; a Concise Treatise on the Constitution, Manufacture, Working, Heat Treatment, and Applications of Alloy Steels, Chiefly Founded on the Researches Regarding Alloy Steels of Sir Robert Hadfield, and with a Foreword by Him. 193 pp. 1923. Sir Isaac Pitman & Sons, London. 5 sh. (Pitman's Technical Primers.)

*Technology Librarian, Carnegie Library of Pittsburgh.

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Brief and non-technical. For students and users of steel.

Central Steel Company. Agathon Alloy Steels. 43 pp. 1922. Massillon, O.

Trade literature, giving properties and applications of special steels.

Dalby, W. E. Strength and Structure of Steel and Other Metals. 176 pp. 1923. Longmans, Green & Co., London. 18 sh.

Author has designed photographic attachments for testing machines, a beam of light tracing a record on a sensitized plate. The book is largely a consideration of his tests and a comparison with the results of other investigators. Metallography receives attention, also.

England—Research Department, Woolwich. German Gun Steels. 16 pp. and plates. 1923. H. M. Stationery Office, London. 3 sh.

Chemical composition, microstructure and mechanical properties of captured German guns.

Fremont, C. Essais de réception des rails. 48 pp. Dunod, Paris. 10 fr.

Fremont, C. Le marteau, le choc, le marteau pneumatique. 194 pp. 1923. Paris.

Friesen, Lennart von. Om syre i jaern. 50 pp. 1922. A. B. Gunnar Tisells, Stockholm.

Occurrence and determination of oxygen in iron and steel.

Geuze, Leon. Forgeage et laminage. 362 pp. 1922. J. B. Baillière et Fils, Paris. 30 fr.

Well illustrated work. The first 150 pages deal with forging and furnaces and the remainder discusses rolling, considering mills of various types.

Goodwin, W. M. A method of Smelting Titaniferous Iron Ore. 25 pp. 1922. Government Printer, Ottawa, Canada. (Honorary Advisory Council for Scientific and Industrial Research. Report No. 8.)

Grigorovitch. [Metallurgy of Iron (in Russian)]. Gosizdat, Moscow.

Guillet, Leon. Les méthodes d'étude des alliages métalliques. 503 pp. 1923. Dunod, Paris. 65 fr.

A thorough study of properties of both ferrous and non-ferrous alloys. Physical testing is treated quite fully, under thermal analysis, variation of volume, electrical resistance, thermo-electricity, magnetism, and various minor tests such as X-ray examination. Includes also metallography and chemical and mechanical tests.

Hayes, Henry. Drop Forging and Drop Stamping. 108 pp. 1923. Sir Isaac Pitman & Sons, Ltd., London. 2 sh. 6 d.

A brief introduction to equipment and methods of the drop-forge shop, and the thermal and mechanical treatment and metallurgy of drop forgings.

Hendel, J. M. New Type of Reductor and Its Application to the Determination of Iron and of Vanadium. 1922. The Author, Park Ave. and 68th St., New York. $1.

Holverscheid, A. Die Walzwerke; Einrichtung und Betrieb. Ed. 2. 144 pp. 1923. Walter de Gruyter, Berlin.

Houghton, (E. F.) & Company. Practical Metallurgy for Engineers. 431 pp. 1923. Philadelphia. $3.

Concerned mainly with ferrous metals, dealing briefly with raw materials and manufacturing processes, and in greater detail with heat treatment, testing and specifications. Non-technical.

Iron and Steel Institute. Carnegie Scholarship Memoirs. Vol. 12, 295 pp. 1923. The Institute, London.

Contains contributions on corrosion, pyrometry, mechanical properties and history.

Iron and Steel Institute. Journal. Vol. 106, 458 pp. 1922. Vol. 107, 807 pp. 1923. The Institute, London.

Iron and Steel Institute. Subject and Name Index to Vols. LXXXIII-CIV, 1911-1921; and to Vols. III-X of the Carnegie Scholarship Memoirs. 335 pp. 1923. The Institute, London. 20 sh.

Jacquet, Alexis. Aciers, fers, fontes. Ed. 2, revised. Vol. 1, 231 pp. 1923. Dunod, Paris. 10 fr.

Concerned with properties, tests and treatment, more than half the book being taken up with heat treatment and cementation.

Ledebur, A. Das Roheisen. Ed. 5, revised by F. Zeyringer. 99 pp. 1924 (sic). Arthur Felix, Leipsic.

Macklin, E. L., and Middleton, E. L. Report on the Grinding of Metals and Cleaning of Castings, with Special Reference to the Effects of Dust Inhalation upon the Workers. 100 pp. 1923. H. M. Stationery Office, London. 4 sh.

Discusses abrasives and grinding machinery used, outlines processes for grinding various products, presents results of physical examination of workmen, and suggests measures for improving hygienic conditions.

Mars, G. Die Spezialstaehle; ihre Geschichte, Eigenschaften, Behandlung, und Herstellung. Ed. 2, revised. 675 pp. 1923. F. Enke, Stuttgart.

Moore, H. F., and Jasper, T. M. An Investigation of the Fatigue of Metals. Series of 1922. 100 pp. 1922. University of Illinois, Urbana, Ill. (Engineering Experiment Station. Bulletin 136.)

Perrott, G. St. J., and Kinney, S. P. Combustion of Coke in Blast Furnace Hearth. 43 pp. 1923. American Institute of Mining and Metallurgical Engineers, New York.

Advance paper, Transactions of the American Institute of Mining and Metallurgical Engineers. An investigation of furnace conditions by means of water-cooled gas-sampling tubes driven into the hearth through the tuyeres.

Piron, Emile. Traité pratique de tracé des cannelures pour cylindres de laminoirs. 244 pp. + 128 plates. 1922. A. De Bœck, Brussels. 50 fr.

Includes a large number of designs representing a Belgian designer's experience of 35 years.

Schomburg, W. Das Eisenhuettenwesen. 125 pp. 1922. Uhlands Technische Bibliothek, Leipsic.

Schoppmann, Rudolph. Eisen und Stahl. Ed. 4, revised by Carl Otto. 100 pp. 1922. B. F. Voigt, Leipsic. 75 cents.

Practical work dealing briefly with manufacture of iron, steel, and alloy steels, and with foundry work.

Schweissguth, P. H. Freiformschmiede. 2 vols. 1922-23. Julius Springer, Berlin.

Tools, methods and materials for forging.

Sisco, Frank T. Technical Analysis of Steel and Steel Works Materials. 543 pp. 1923. McGraw-Hill Book Co., New York. $5.

In addition to analytical methods, nearly one-third of the book is devoted to laboratory design and equipment.

Snodgrass, J. M., and Guldner, F. H. An Investigation of the Properties of Chilled Iron Car Wheels. University of Illinois, Urbana, Ill.

Pt. 1: Wheel Fit and Static Load Strains. 103 pp. 1922. 55 cents. (University Experiment Station, Bulletin 129.)

Pt. 2: Wheel Fit, Static Load, and Flange Pressure Strains. Ultimate Strength of Flange. 72 pp. 1922. 40 cents. (University Experiment Station. Bulletin 134.)

Pt. 3: Strains Due to Brake Application, Coefficient of Friction and Brake-Shoe Wear. 100 pp. 1923. 50 cents. (University Experiment Station. Bulletin 135.)

Stahlwerks-Verband A.-G. Abteilung Eisenbahn-Oberbaustoffe, Duesseldorf. Abschnitt 1-10, 1922. Duesseldorf.

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A series of pamphlets giving dimensions and properties of rails, plates and other railway materials in rolled steel.

Stillman, Albert Leeds. Briquetting. 466 pp. 1923. Chemical Publishing Co., Easton, Pa. $6.

Practical methods. Concerned largely with fuel, but including metal wastes.

Stoughton, Bradley. Metallurgy of Iron and Steel. Ed. 3. 519 pp. 1923. McGraw-Hill Book Co., New York. $4.

A thorough revision of this well known text-book. Many parts have been rewritten to bring them thoroughly up to date and the material added has been so extensive that the chapter on "Physics and Chemistry Introductory to Metallurgy" has been omitted from this edition.

Tafel, Wilhelm. Walzen und Walzenkalibrieren. Ed. 2 and 3, enlarged. 303 pp. 1923. Fr. Wilhelm Ruhfus, Dortmund. $1.60.

United States—Interstate Commerce Commission. Report on the Transverse Fissures in Steel Rails and Their Prevalence on Certain Railroads. 169 pp. 1923. Government Printing Office, Washington, D. C.

Remedy is through proper grade of steel and regulation of loads. Requires co-operation between railroads and steel mills.

Verein deutscher Eisenhuettenleute. Waermestrom-Bilder (Sankey-Diagramme) aus dem Eisenhuettenwesen. n. p. 1922. Verlag Stahleisen, Duesseldorf. 45 cents.

Brief text and numerous diagrams illustrating heat flow in various kinds of metallurgical equipment.

Vernon, Thomas H. Special Steels. 153 pp. 1923. Sir Isaac Pitman & Sons, New York.

A rapid survey of alloy steels now in use.

Vosmaer, A. Ijzer en Staal; hun Bereiding, Verwerking, Eigenschappen en Toepassingen.

Pt. 3: Eigenschappen, Onderzoek, en Toepassingen. 204 pp. 1922. A. W. Sijthoff's Uitgeversmaatschappij, Leyden. $1.45.

Wuest, Fritz, ed. Mitteilungen aus dem Kaiser-Wilhelm-Institut fuer Eisenforschung zu Duesseldorf. Vol. 4. 163 pp. + 16 plates. 1922. Verlag Stahleisen, Duesseldorf.

Contains numbers 21-31 continuing the series of theoretical papers on iron and steel published in earlier volumes.

Economics, Statistics, Directories.

American Iron and Steel Institute. Annual Statistical Report for 1922. 98 pp. 1923. The Institute, New York. $3.50.

Statistics of production, consumption and prices of raw and finished products of the steel industry.

Andresen Company, Inc. Directory Giving List of Companies Operating Blast Furnaces, Steel Plants, Rolling Mills and Allied Industries; Forging and Stamping Plants in the United States and Canada, together with List of Executives and Operating Officials. 174 pp. 1923. Pittsburgh. $5.

Association des Maitres de Forges de Lorraine. L'Industrie sidérurgique en Lorraine en 1921 et 1922. The Association, Metz.

Bensinger Iron and Steel Code. 120 pp. 1923. C. Bensinger Co., New York. $7.50.

"First complete cable and telegraph code covering the Iron and Steel Trade in general. * * * Contains over Nineteen Thousand five-letter words with at least a two-letter variation."—*Preface.*

Burchard, Ernest F., and Davis, H. W. Iron Ore, Pig Iron and Steel in 1921. Published April 23, 1923. Government Printing Office, Washington, D. C.

Advance publication comprising pp. 565-597 of the United States Geological Survey's "Mineral Resources of the United States, 1921," Part I.

Butler, J. G., Jr. Fifty Years of Iron and Steel. Ed. 7.

"Contains the addition of a chapter which recites the beginning and development of the open-hearth process of steel manufacture in the United States. Several illustrations also have been added to the book. . . It has become an authoritative treatise of the rise of American iron and steel manufacture for two-thirds of a century up to the present day, rich in historical facts and marked by color and personal reminiscences."—*Iron Trade Review,* Nov. 15, 1923.

Colliery Year Book and Coal Trades Directory, 1923. 844 pp. 1923. Louis Cassier Co., Ltd., London. 12 sh.

Lists of officials, owners, producers, merchants, etc., also of gas works, electric plants and blast-furnaces.

Cotter, Arundel. La corporation de l'acier aux Etats-Unis. Translated by André Aude. 238 pp. 1923. Vuibert, Paris. 10 fr.

Jensen, Carl. Cost Problems in the Wrought Iron Industry. National Association of Cost Accountants, New York.

Deals particularly with cost accounting in the manufacturing of muck bar, skelp, and pipe.

Metal Statistics. Ed. 16. 512 pp. 1923. American Metal Market Co., New York. $1.

Statistical information on both ferrous and non-ferrous metals.

National Federation of Iron and Steel Manufacturers. Statistics of the Iron and Steel Industries. 83 pp. The Federation, London. 5 sh. 4 d.

Detailed figures and records of iron and steel production of the world, over an extended period.

Olds, M. Analysis of the Inter-Church World Movement Report on the Steel Strike. 1922. G. P. Putnam's Sons, New York. $2.50.

Rodale, J. I. War-Time Depreciation in Open Hearth Steel Plants and Rolling Mills. 1923. National Association of Cost Accountants, New York. 75 cents.

Skinner, Walter R. Mining Manual and Mining Year Book for 1923. 824 pp. 1923. Author, London. 21 sh. 6 d.

Primarily an investors' manual, giving brief information on many mining and metallurgical companies, mainly British. Includes some coal and iron companies.

Tross, Arnold. Der Aufbau der Eisen- und Eisenverarbeitenden Industrie-Konzerne Deutschlands. 1923.

Wagner, Joseph. La siderurgie luxembourgeoise avant la découverte du gisement des minettes; histoire technique du bon viex temps. 209 pp. Paul Schroell, Diekirch, Luxemburg.

Electrometallurgy and Other Applications of Electricity.

Association of Iron and Steel Electrical Engineers. Proceedings. 1922. 968 pp. 1923. The Association, Pittsburgh. $5.

Coussergues, C. Clausel de. L'electrosidérurgie, fabrication de l'acier au creuset. 416 pp. J. B. Baillière et Fils, Paris. 50 fr.

Rademacher, W. H., comp. Lighting of Steel Mills and Foundries. 32 pp. 1923. Edison Lamp Works of General Electric Company, Harrison, N. J. (Lighting Data. Index 66, Bulletin L. D. 150.)

"Bibliography," p. 32.

Russ, E. F. Die Elektro-metallschmelzöfen. 161 pp. 1922. R. Oldenbourg, Munich.

Stansfield, Alfred. Electric Furnace for Iron and Steel. 453 pp. 1923. McGraw-Hill Book Co., New York. $5.

Supersedes author's "Electric Furnace" published in 1907 and again in 1913. Includes smelting and steel making and is valuable for description of types and for operating data. A later volume will deal with general principles and non-ferrous applications.

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Foundry Practice.

Dwyer, Pat. Tales from the Gangway. 450 pp. 1923. Penton Publishing Co., Cleveland, O. $3.

"Each article is introduced in anecdotal and somewhat humorous fashion and concludes with a good deal of practical instruction on foundry method. * * * Makes interesting reading for the average foundry worker who does not want his technical reading to be too technical."—*Iron Age*, April 5, 1923.

Everitt, Frank, and Heywood, Johnson. Cost Control for Foundries. Edited by William R. Basset. 226 pp. 1923. McGraw-Hill Book Co., New York. $3.

Includes a large number of forms, and indicates those adapted to the small foundry.

Foundrymen's Handbook. Revised ed. 309 pp. 1922. Penton Publishing Co., Cleveland, O. $5.

Not a manual of foundry practice but a collection of tables and data for reference.

Hanley, Edmund C. Wood Pattern Making. 191 pp. 1922. Bruce Publishing Co., Milwaukee.

Well illustrated text, primarily for manual training schools.

Horner, Joseph G. The Modern Ironfoundry. 255 pp. 1923. Henry Frowde and Hodder & Stoughton, London. 15 sh.

A general work on materials and methods. Partly reprinted from British trade journals.

Irresberger, Carl. Der Kupenlofenbetrieb. 54 pp. 1922. Julius Springer, Berlin.

Kirk, E. Dr. Edward Kirk's System of Foundry Practice; Dry Sand Cores. 1922. The Author, 938 N. 10th St., New York. $12.50.

McCracken, Edward M., and Sampson, Charles H. Pattern-Making. 111 pp. 1923. D. Van Nostrand Co., New York. 10 sh. 6 d.

Includes some discussion of foundry methods.

Parsons, S. J. Practical Moulding. 136 pp. George Routledge and Sons, London. 5 sh.

A straightforward introduction to foundry practice.

Stadtmueller, Hugo. Die Schmelzoefen der Eisen-Stahl- und Metallgiesserei. Ed. 2, enlarged. 325 pp. 1922. Gutsch, Karlsruhe.

United States—Bureau of Labor Statistics. Safety Code for the Protection of Industrial Workers in Foundries. 12 pp. 1923. Government Printing Office, Washington, D. C.

Tentative American Standard, Approved by American Engineering Standards Committee. Sponsored by National Founders' Association, and American Foundrymen's Association.

Wendt, R. E. Foundry Work; a Text on Molding, Dry-Sand, Core-Making, and the Melting and Mixing of Metals. 206 pp. 1923. McGraw-Hill Book Co., New York. $2.

Text-book for students and apprentices.

Furnaces, Heat Treatment.

American Society for Steel Treating. Handbook of the American Society for Steel Treating. Loose leaf. Preface dated Dec., 1923.

Object is "to present, in a concise form, charts, data and other information pertaining to the manufacture or treatment of metals." Material is unindexed. Classification provides for 25 subjects, either special steels or processes.

Brearley, Harry. Die Werkzeugstahle und ihre Waermebehandlungen. Translated by Rudolf Schaefer. Ed. 3, 324 pp. 1923? Julius Springer, Berlin.

Fuels and Furnaces. Monthly. F. C. Andresen & Associates, Inc., Pittsburgh.

A journal devoted to fuels, furnaces, ovens, kilns, and industrial heating in all its phases. Contains original papers and numerous abstracts from other technical and trade journals. First issued in May, 1923, the eight numbers issued during the year form a total of 862 pages.

Groume-Grjimailo, W. E. Flow of Gases in Furnaces. Translated from Russian into French by Leon Dlougatch and A. Rothstein, with a Preface by Henry Le Chatelier; translated from the French by A. D. Williams, with an Appendix upon the Design of Open-Hearth Furnaces. 399 pp. 1923. John Wiley & Sons, New York. $5.50.

Contains bibliographical foot-notes.

"This book is built up about a helpful analogy which regards the flow of hot gases in furnaces as resembling inverted streams of fluid, flowing along the tops of furnaces and flues, over inverted weirs, and exerting quite appreciable pressures as their height increases. . . The development of the analogy, the presentation and use of the formulas, for the flow of hot gases over inverted weirs, and the application of these principles to the design of reverberatory furnaces and kilns of various types, are the most valuable portions of the book."—*Industrial and Engineering Chemistry*, 1923.

Simon, Eugen. Haerten und Vergueten. Ed. 2. 2 vol. 1923. Julius Springer, Berlin. (Werkstattbuecher, pt. 7-8.)

Trinks, Willibald. Industrial Furnaces. Vol. 1, 319 pp. 1923. John Wiley & Sons, New York. $4.50.

The first work to deal at all adequately with the theory of industrial-furnace design. Volume one is confined to fundamental principles and will be of special value in connection with reheating furnaces for steel. The analysis of specific applications is reserved for volume two.

Refractories.

Bischoff, Carl. Die feuerfesten Tone und Rohstoffe. Ed. 4, revised by K. Jacobs and E. Weber. 266 pp. 1923. J. A. Barth, Leipsic.

Schwartz, Robert. Feuerfeste und hochfeuerfeste Stoffe. Ed. 2, enlarged. 1922. F. Vieweg, Brunswick.

Searle, Alfred B. Chemistry and Physics of Clays and Other Ceramic Materials. 634 pp. 1923. Ernest Benn, Ltd., London. 55 sh.

Gives some attention to the requirements of steel manufacturers.

Searle, Alfred B. Refractories for Furnaces, Crucibles, etc. 170 pp. 1923. Sir Isaac Pitman & Sons, Ltd., London. 5 sh.

Deals briefly with materials, shaping, drying, and burning.

Searle, Alfred B. Refractory Materials; Their Manufacture and Use. Ed. 2. 2 vols. Charles Griffin & Co., London. 42 sh.

Stainless Steel, Corrosion.

Firth-Sterling Steel Company. Firth-Sterling Stainless Steel. 61 pp. 1923. McKeesport, Pa. $1.

A valuable work, dealing with history, applications, treatment and properties.

Hamlin, Marston Lovell, and Turner, F. M., Jr. The Chemical Resistance of Engineering Materials. 267 pp. 1923. Chemical Catalog Co., New York. $5.

Compilation of data on the action of industrial chemicals on metallic and non-metallic structural materials. Devotes considerable attention to corrosion of iron and steel.

Polansky, Victor S., comp. Stainless Steel and Stainless Iron; a List of References to Material in the Carnegie Library of Pittsburgh. 21 pp. 1923. Free. (Postpaid, 5 cents.) Carnegie Library of Pittsburgh, Pittsburgh.

Annotated list of more than 200 references.

Pollitt, Alan A. The Causes and Prevention of Corrosion. 230 pp. 1923. D. Van Nostrand Co., New York. $6.50.

A reasonably thorough survey of corrosion and its prevention.

Structural Steel.

American Institute of Steel Construction. Standard Specification for the Design, Fabrication, and Erection

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of Structural Steel for Buildings. 23 pp. 1923. The Institute, Cleveland, O.

Association of American Steel Manufacturers. Manufacturers Standard Specifications for Structural and Boiler Steel. Revised Nov. 24, 1922. 12 pp. 1923. The Association, Pittsburgh.

Bethlehem Steel Company. Lackawanna Steel Sheet Piling. 25 pp. 1923. Bethlehem, Pa. (Bulletin 10.)
Gives dimensions, weights, properties, connections and splices.

Bland, M. C. Handbook of Steel Erection. 241 pp. 1923. McGraw-Hill Book Co., New York.
For the civil engineer and contractor, and not concerned with metallurgy.

Carnegie Steel Company. Extracts from Carnegie Pocket Companion, for Engineers, Architects and Builders. 156 pp. 1923. Pittsburgh.
Condensed information and tables pertaining to structural steel.

Carnegie Steel Company. Shape Book. Ed. 9, 346 pp. 1923. Pittsburgh.

Lloyd's Register of Shipping. Jordan's Tabulated Weights of Iron and Steel Sections and Other Information, for the Use of Naval Architects, Shipbuilders and Manufacturers. Ed. 8. 317 pp. 1923. E. & F. N. Spon, Ltd., London. 15 sh.

Skelton (R. A.) & Company. Broad-Flange Beams, Grey Process. London. 5 sh. (Handbook No. 18.)
The first of a new series of Skelton's structural steel handbooks. Supersedes numbers 10 to 14 dealing with pre-war sections which are obsolete and are no longer rolled by the firm.

UNITED STATES GOVERNMENT PUBLICATIONS

Certain publications listed below may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C.

UNITED STATES BUREAU OF STANDARDS

Circulars.

No. 58. Invar and Related Nickel Steels. Ed. 2. 93 pp. 1923. 30 cents.

Scientific Papers.

No. 448. Decarburization of Ferrochromium by Hydrogen, by Louis Jordan and F. E. Swindells. 327-334 pp. 1922. 5 cents.

No. 452. Structure of Martensitic Carbon Steels and Changes in Microstructure Which Occur upon Tempering, by Henry S. Rawdon and Samuel Epstein. 373-409 pp. 1922. 15 cents.

No. 453. Preparation and Properties of Pure Iron Alloys. Pt. 1: Effects of Carbon and Manganese on the Mechanical Properties of Pure Iron, by Robert P. Neville and John R. Cain. 411-443 pp. 1922. 10 cents.

No. 457. Gases in Metals. Pt. 1: The Determination of Combined Nitrogen in Iron and Steel and the Change in Form of Nitrogen by Heat Treatment, by Louis Jordan and F. E. Swindells. 499-511 pp. 1922. 5 cents.

No. 458. Apparatus for the Determination of the Magnetic Properties of Short Bars, by M. F. Fischer. 513-526 pp. 1922. 5 cents.

No. 463. Preparation and Properties of Pure Iron Alloys. Pt. 2: Magnetic Properties of Iron-Carbon Alloys as Affected by Heat Treatment and Carbon Content, by W. L. Cheney. 609-635 pp. 1922. 15 cents.

No. 464. Preparation and Properties of Pure Iron Alloys. Pt. 3: Effect of Manganese on the Structure of Alloys of the Iron-Carbon System, by Henry S. Rawdon and Frederick Sillers, Jr. 637-653 pp. 1922. 10 cents.

Technologic Papers.

No. 228. Lathe Breakdown Tests of Some Modern High-Speed Tool Steels, by H. J. French and Jerome Strauss. 183-225 pp. 1923. 15 cents.

No. 229. Some Tests of Steel-Wire Rope on Sheaves, by Edward Skillman. 227-243 pp. 1923. 10 cents.

No. 235. Thermal Stresses in Steel Car Wheels, by George K. Burgess and G. Willard Quick. 367-403 pp. 1923. 15 cents.

No. 241. A Comparison of the Deoxidation Effects of Titanium and Silicon on the Properties of Rail Steel, by George K. Burgess and G. Willard Quick. 581-635 pp. 1923. 10 cents.

UNITED STATES BUREAU OF FOREIGN AND DOMESTIC COMMERCE

Trade Information Bulletins.

No. 6. The Brazilian Iron and Steel Industry, by W. L. Schurz. 11 pp. 1922.

No. 11. The Steel-Making Facilities of Great Britain, by H. B. Allin Smith. 9 pp. 1922.

No. 35. Iron and Steel Industry and Trade of Poland, by H. B. Smith. 12 pp. 1922.

No. 66. Statistical Record of the British Iron and Steel Industry, by H. B. Allin Smith. 13 pp. 1922.

No. 96. German Iron and Steel Industry, by C. E. Herring. 13 pp. 1923.

No. 133. The British Steel Industry, by H. B. Allin Smith. 22 pp. 1923.

Zinc Production in Norway

The Ilen Smeltevaerk, in Trondhjen, Norway, has now resumed its operations for the manufacture of zinc, and it is expected that the production will increase in the course of the year, according to the Norges Handels-og Sjofartstidende. The works has received a cargo of 2,000 tons of zinc ore from Mexico.

Ilen Smeltevaerk is owned by Mr. Tharaldsen, the inventor of a new process for the manufacture of zinc, who also owns the Jossingfjord Fabrikker, which is now working at full capacity. The Belgium Zinc Syndicate has acquired rights to utilize the Tharaldsen methods for zinc manufacture, and the syndicate will soon commence operations, as it has rented 20,000 horsepower electric energy from the Tyssefaldende in Hardanger.

The zinc ore used in Norway for the manufacture of zinc is taken from Spain and Mexico, the bulk coming from the latter country. Some zinc ore is also found in Norway, and Mr. Tharaldsen has experimented with Norwegian ore for the manufacture of zinc. These experiments are said to have been very satisfactory.

An important by-product, sulphur, is obtained from the manufacture of zinc, and can be produced in such quantities that it might seriously threaten the Norwegian pyrite industry.

Straits Trading Report

The report of the Straits Trading Company, Ltd., for the half year ended March 31 shows that during that period a net profit of $604,765.44 was made. With the balance of $438,342.60 brought forward from the last account, this made a total of $1,043,108.04 available at the end of the half year.

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Chicago Points With Pride

Historical Sequences in the Development of a Truly Remarkable Steel Unit.

By F. J. CROLIUS

THE Inland Steel Company have built and are expanding one of the finest concentrations of modern steel producing facilities that can be found anywhere in the world.

If we were to take a map of the United States, and carefully search for the ideal location, weighing all the advantages against the limitations, this section of splendid lake front would probably mark the end of our quest.

Then if we were to call into consultation the best minds in steel engineering and give them carte blanche to design an ideal economic unit, the result of their labors would closely resemble the Indiana Harbor plant as it will look when the expansions now under construction are in full operation.

Lake ore in company vessels, coal and limestone are assembled directly at the blast-furnaces. Coke from this coal is made in modern by-product ovens located in the heart of the plan. Scrap is abundantly available over a veritable network of communicating railroads, both trunk line and belt-line, and shipments of finished material enjoy the same facilities for distribution.

Being the center of a great steel producing area, labor is familiar with the activities involved, and a floating supply is always available to draw upon.

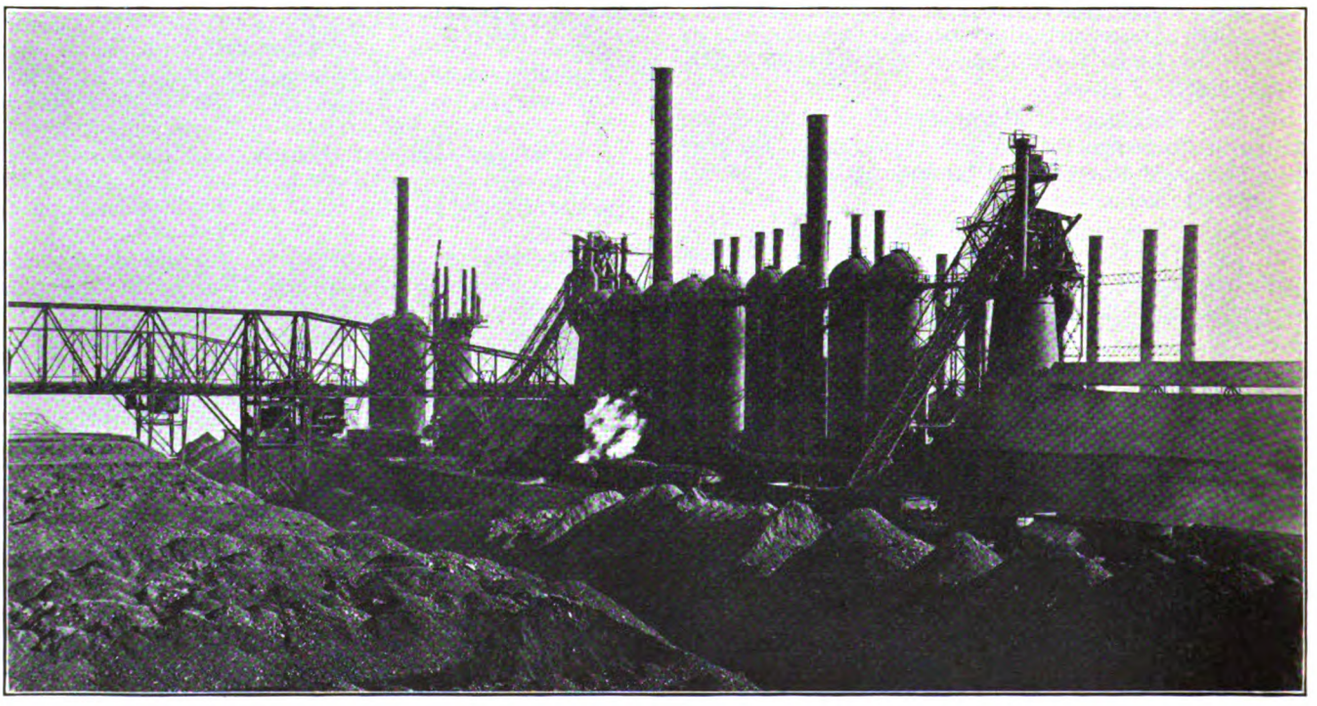
Gas and tar from coke-ovens is conveniently carried to nearby furnaces, and power generated from blast-furnace gas finds ready application in the motor driven mills.

Water, which is so vital to all great blast furnaces, coking operations, and mill practices, is forever abundant, directly from the Great Lakes, a source which guarantees an unfailing supply of clear, alkaline water requiring the very minimum of conditioning, not subject to the variations of seasonal floods, famines, contaminations or variations in level.

From every angle, Inland Steel presents the picture of an engineered layout—not just a hetrogeneous collection of mills of various sizes and for various purposes, which have grown from some vague historical source into a great tangle, whose only apparent points of contact are the lines of railroad track, the inter-connected steam lines, gas and water lines, or power-lines; the first impression is one of magnitudes finely balanced for a definite purpose, and the ultimate impression is a clear consciousness that what was in the minds of the original builders has been projected forward into an assembled whole.

In the detailed description of a great steel plant it is customary to secure authentic information from those officials and operating executives qualified to produce it. We are indebted in this case to Mr. William A. Maxwell, Jr., General Superintendent; Mr. Carl Smith, Steam Engineer, and Mr. H. R. de Holl, Superintendent of By-Product Coke Plant; their articles are incorporated without revision.

The Inland Steel Company was incorporated October 30, 1893, for the purpose of building and operating a rolling mill for the rolling of old rails into mer-



A remarkable picture of the group of blast furnaces at Inland Steel Company, showing the new No. 3 furnace in the distance.

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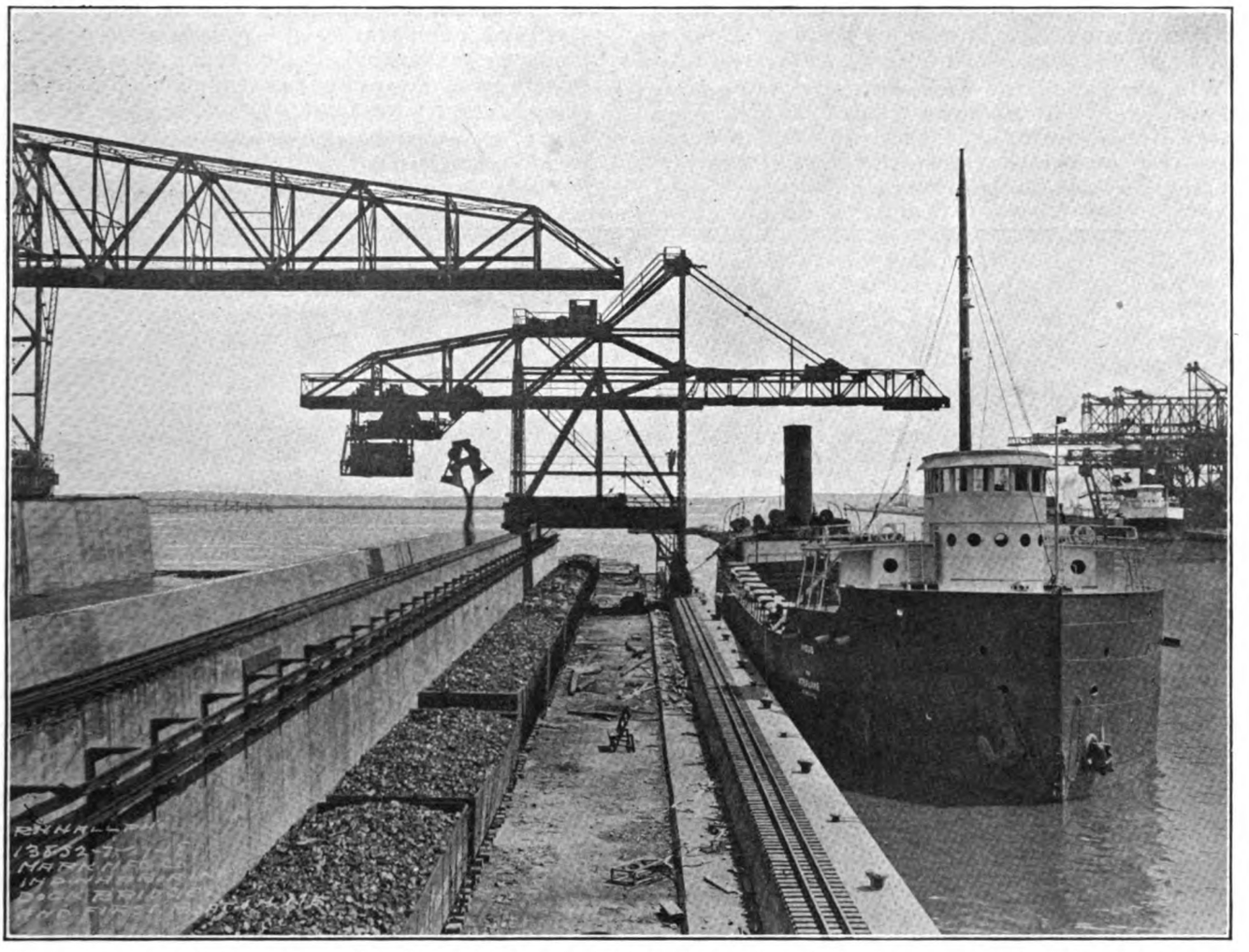

This view of the lake front gives a clear idea of the transportation facilities. One of the company steamships alongside her pier, with gantry unloader in position, aand ore bridge extension at the left.

chant bars, small angles, etc. This plant was located at Chicago Heights, Ill., and at the present time has an annual capacity of 50,000 tons of bars and occupies about five acres of ground.

Early in 1900 it was decided to build an open hearth plant for the manufacture of open hearth steel. In 1901 the company acquired property at Indiana Harbor, Ind., and began the erection of a modern open hearth steel plant.

The plant as now constituted consists of 130 by-product coke ovens with complete equipment for recovery of all by-products, three modern blast furnaces, 26 open hearth furnaces, blooming mills, sheet bar mill, rail mill, bar mills, sheet mills, plate and structural mills, splice bar and tie plate departments and bolt and spike mill, together with all the necessary equipment for complete operations, such as steam, electrical and motive power and machine shops.

The company owns an interest in the Inland Steamship Company which operates two ore boats of 10,000 tons capacity each for transportation of ore, coal and limestone.

The company owns directly or indirectly leases or interests in leases on seven iron ore properties in Mesaba and Cuyuna Ranges; and also owns directly or indirectly interest in four coal properties located in Pennsylvania, West Virginia and Illinois.

The estimated annual capacity of the plants at Indiana Harbor, Ind., and Chicago Heights, Ill., is as follows:

By-products coke, net tons	550,000
Coal tar, gallons	7,000,000
Sulphate of ammonia, lbs.	17,000,000
Light oil products, gallons	2,000,000
Pig iron, gross tons	600,000
Open hearth steel ingots, gross tons	1,200,000
Blooms and slabs, gross tons	1,200,000
Sheet bar and billets, gross tons	350,000
Structural shapes, gross tons	210,000
Rails, gross tons	240,000
Bars, gross tons	170,000
Sheared plates, gross tons	200,000
Sheets, net tons	120,000
Tie plates, gross tons	30,000
Splice bars, gross tons	30,000
Rivets, track spikes and bolts	30,000

The additional finishing capacity now under construction will increase the annual capacity of finished steel products by approximately 185,000 tons.

The company owns over 600 acres of land at Indiana Harbor, Ind., with frontages on the southern shore of Lake Michigan and the government ship canal, where its main plant is located.

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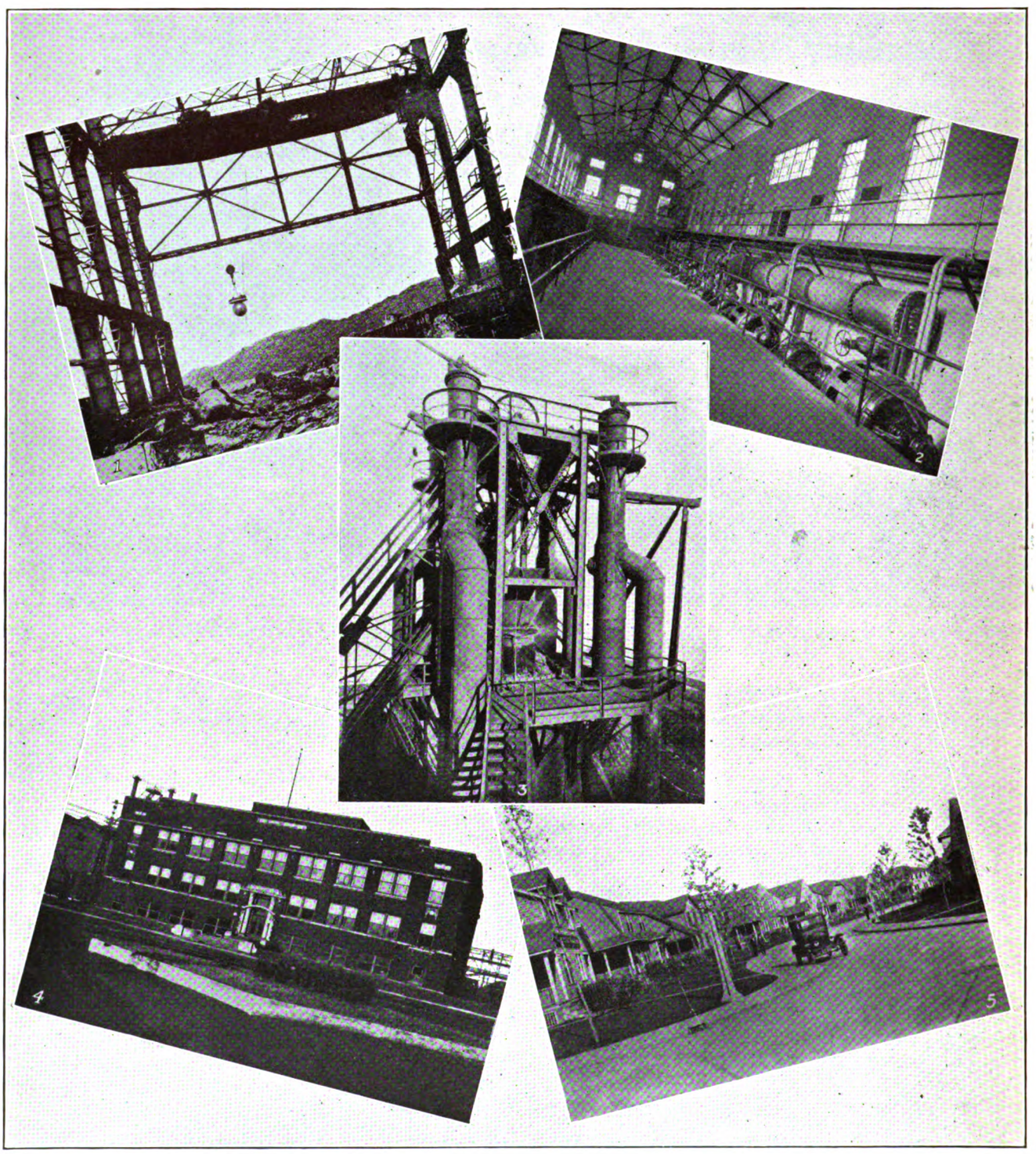
The company also owns more than 800 acres of land fronting on Lake Michigan in Porter County, Ind., about seven miles east of Gary, Ind.

With the harbor and docks alongside its property and connection with the main lines of the New York Central, Pennsylvania, and Baltimore & Ohio systems, the company's transportation facilities are favorable for both water and rail shipments.

The plant was started in 1902, the equipment consisting of four 50-ton open hearth furnaces fired with producer gas; one 32-in. reversing blooming mill driven by a 30x48-in. twin simple non-condensing engine through reduction gears; one 24-in. two high four stand bar and structural mill driven by a 36x48-in. twin simple non-condensing engine built by Wm. Todd & Company; one sheet mill unit consisting of



1—Against the sky-line, the high structure involved in skull-cracker operation stands out in bold relief. Note the magnet and ball suspended. 2—It would be difficult to secure a better picture of this modern pumping station. All pumps are motor driven, and the general arrangement is ideal for easy inspection and careful maintenance. 3—Shows a typical blast-furnace top in detail. 4—Main entrance to the by-product coke plant, showing the new general office building. 5—Shows a street in the recently developed real estate sub-division. Comfortable houses with little of the aspect usually associated with steel works' dwellings.

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eight hot mills and one jobbing mill, also three stands of cold rolls. This line of sheet mills was driven through reduction gears by a 30x60-in. twin simple non-condensing engine built by Filer & Stowell Company. The 24-in. bar mill was built by Garrett-Cromwell Company and consisted of pinions, a universal roughing stand and three stands of finishing rolls. About two years after the mill was started, this universal stand was replaced by a similar universal mill built by the Garrison Foundry Company. The mill rolls I-beams from 3 in. to 12 in., channels from 3 in. to 13 in., angles from 3x2 in. to 6x6 in., rounds from 2 in. to 4½ in., and flats from 3x¼ in. to 22x¼ in. The mill is arranged so that flats can be rolled on the universal mill, while roll changes are being made on the finishing stands.

When the mill started the steam boiler equipment consisted of eight 464-hp. Stirling boilers fired with Jones underfeed stokers and two 250-hp. Van Dyke boilers hand fired. As the Van Dyke boilers were only constructed for 100 lbs. steam pressure, that was the pressure carried on all the boilers.

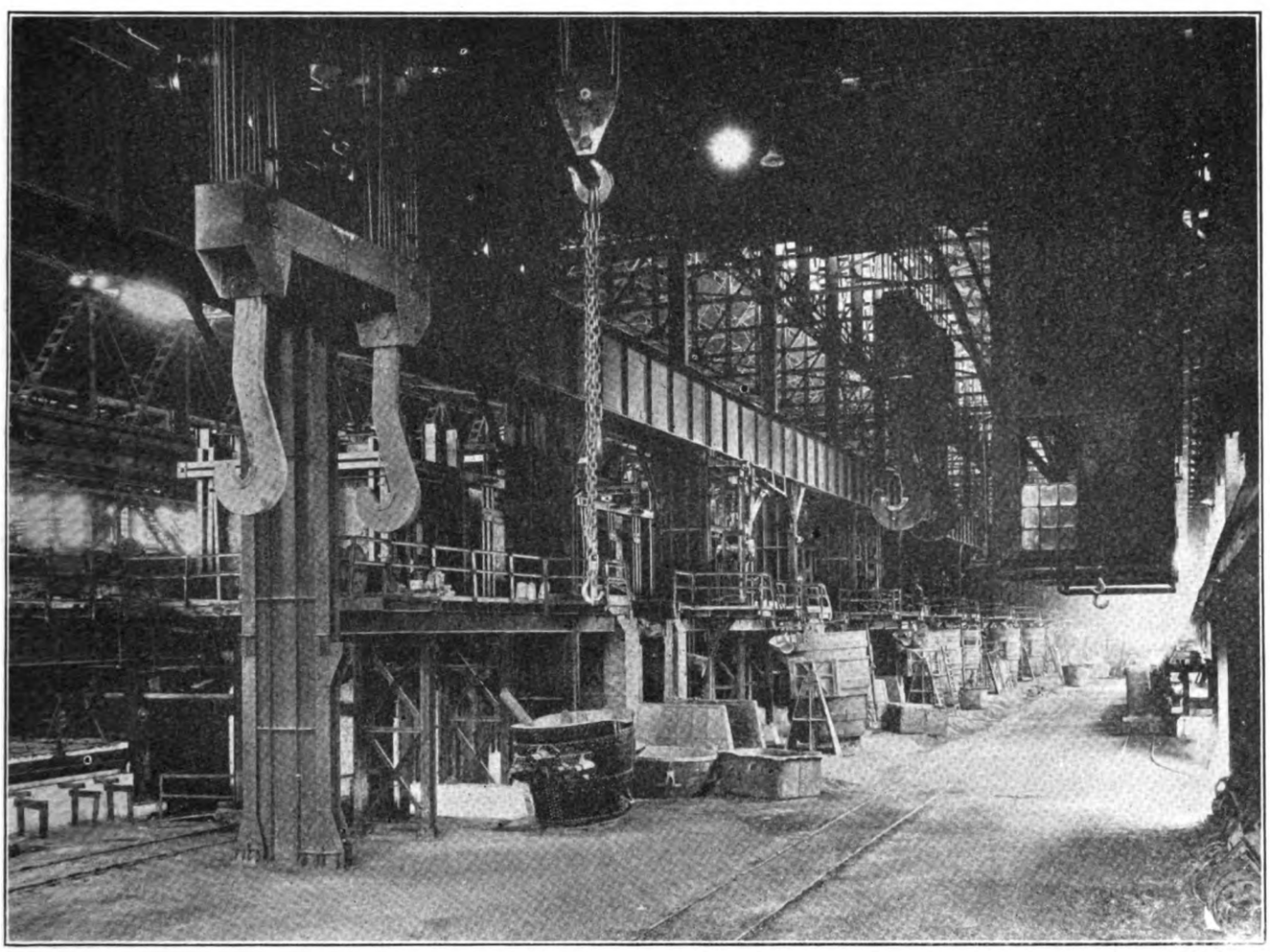
All mill auxiliaries such as tables, shears, etc., were driven by small steam engines.

The electric power for lights and cranes was furnished by two 125-kw. and one 75-kw., 250-volt, d.c. generators driven by high speed Ideal engines.

The general service water was furnished by two 20x12x18 duplex steam pumps getting their water from a small stream which emptied into Lake Michigan on the present site of the Indiana Harbor ship canal.

In 1905 four more 464-hp. Stirling boilers with Jones stokers were added and the two Van Dyke boilers discarded. This allowed the steam pressure to be raised to 150 lbs. gauge.

During the next five-year period from 1906 to 1910 the plant expanded very rapidly, the equipment added being the first 400-ton blast furnace located at Plant 2, together with the ore docks and two ore bridges, eight 464-hp. Stirling blast furnace gas fired boilers, four vertical steam driven blowing engines and a d.c. power station containing three 550-kw., 250-volt, d.c. engine-driven generators. This power station was connected to Plant 1 by underground cables, allowing the removal of the small generating units at Plant 1; the 32-in. blooming mill was replaced by a 36-in. reversing blooming mill built by the United Engineering & Foundry Company. The old engine was replaced by a 50x66-in. twin simple reversing engine built by the Mesta Machine Company. The engine was connected to the mill without gear reduction; at the same time the above changes were made on the blooming mill a 24-in. three stand three high mill was installed in line with the blooming mill to roll blooms from the blooming mill into sheet bar, slabs and billets without reheating. This mill was built by the



The main open-hearth mill in operation, showing ladles located in position for tapping.

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United Engineering & Foundry Company and was driven by a 38-in. and 72x60-in. tandem compound engine built by the Mesta Machine Company. A continuous merchant mill was added consisting of six stands of 14-in. roughing rolls, two stands of 14-in. intermediate rolls and four stands of 11-in. and two stands of 8-in. rolls in the finishing train. This mill was built by the Morgan Construction Company and is driven by a 32-in. and 56x60-in. tandem compound engine exhausting into a barometric condenser. The mill is served by two 12 ft. by 36 ft. 8 in. Morgan continuous heating furnaces fired with producer gas furnished by four 8-ft. Morgan stationary producers.

No. 2 sheet mill unit was added in line with No. 1 unit. The new unit consisted of eight hot mills and one jobbing mill and is driven through reduction gears by a 34 in. and 60x60-in. cross compound engine built by the Mesta Machine Company. The mills were built by the United Engineering & Foundry Company.

A galvanizing and roofing department was installed equipped with eight galvanizing pots.

Four additional 50-ton open hearth furnaces were installed.

To furnish the general service water for the above mills a 6,000,000-gallon Heisler cross compound pumping engine was installed at the boiler house pumping station, getting its water from a well fed by a 30-in. gravity line from the Indiana ship canal.

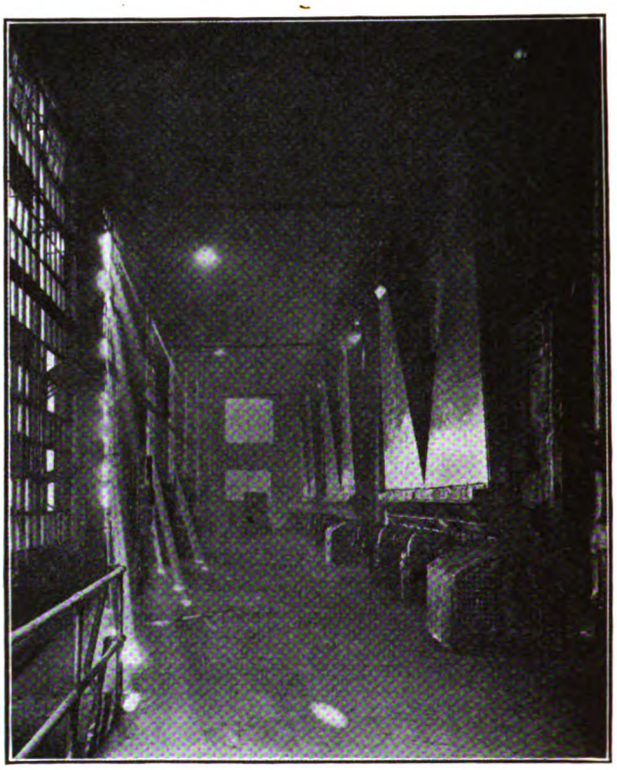
Also a new pumping station was built at the northwest end of the Plant 1 yard, which borders on the Indiana Harbor ship canal. In this station were installed two 8,000,000-gallon Nordberg cross compound pumping engines. To furnish steam for the added engines and pumps, 12 464-hp. Stirling boilers equipped with Green chain grates were installed in Plant 1 boiler house, making 22 boilers in all.

In 1911 the second blast furnace was installed. Three additional blowing engines were added and two 550-kw., 250-volt, d.c. engine-driven generators, duplicates of the first three. Eight additional 464-hp. Stirling gas-fired boilers were added in the boiler house.

In 1911 the bolt and rivet department was installed with four nut machines, six rivet machines and three spike machines. These machines were first equipped with oil fired furnaces, but since 1914 have used coke oven gas.

In 1912 and 1913 four 50-ton open hearth furnaces were added to Plant 1, making 12 furnaces in the battery; the first battery of Koppers by-product coke ovens were installed and the 24-in. bar mill furnaces, the sheet mill annealing pits and jobbing mill furnaces, and the bolt and rivet furnaces were switched over from oil firing to coke oven gas; a new double track tunnel was constructed under the New York Central, Baltimore & Ohio and E., J. & E. rights of way, connecting Plants 1 and 2. A 90-in. three high sheared plate mill built by the United Engineering & Foundry Company was installed at Plant 1. The mill was served by three 9x35-ft. Laughlin continuous reheating furnaces fired with producer gas furnished by Morgan stationary producers. It was decided to use an electric drive on this mill and to replace the old Filer & Stowell engine on No. 1 sheet mill unit with a motor. A 2,000-hp. Westinghouse 2,200-volt, 3-phase, 25-cycle motor was installed to drive the plate mill, while a 1,600-hp. Westinghouse 2,200-volt, 3-phase, 25-cycle motor was installed to drive the sheet mill. To furnish a.c. power for these two mill motors, Plant 1 a.c. station was installed consisting of two 2,500-kva., 2,200-volt, 3-phase, 25-cycle generators driven by Westinghouse low pressure turbines operating on the exhaust steam from the 24-in. bar mill and 36-in. blooming mill engines through two Rateau regenerators. The turbines exhaust into surface condensers, which get their cooling water from two 10,000 G. P. M. motor driven centrifugal pumps located in the canal pumping station.

In 1914 Nos. 1 and 2 open hearth furnaces were equipped with waste heat boilers. A 400-hp. Garbe boiler was put on No. 1 furnace and a 402-hp. Heine boiler put on No. 2 furnace. During 1915 and 1916 the remaining 10 furnace were equipped with 422-hp. Babcock & Wilcox cross drum waste heat boilers. Each



A glimpse through one of the boiler houses.

boiler is equipped with a Foster superheater located in the waste gas flue in front of the boiler, and a Green radial flow induced draft fan driven by a Terry steam turbine through a Westinghouse reduction gear.

From 1915 to 1917 extensive additions were made to the works at Plant 2. The third blast furnace was installed of 550 tons capacity. The ore dock and ore field was extended and three 6-ton Hoover & Mason ore bridges were added to the unloading equipment, making a total of five 6-ton ore bridges and two Robbins coal unloaders on the dock. The five bridges can move 1,000 tons of ore per hour from the ore boats to the stock pile, while the two Robbins coal unloaders can handle 600 tons of coal per hour from the coal belts to the belt conveyor which transports the coal to the coal field. Three additional blowing engines were installed, making a total of 10. Five of these are high pressure engines 44 in. and 84x60 in., and five low pressure engines 84 in. and 84x60 in. They are piped up so that they can be operated in pair as cross com-

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pound engines. All these engines exhaust into one barometric condenser. The blowing engines were built by the Allis Chalmers Company. Two engine-driven d.c. generators were installed in the d.c. station, making a total of seven 550-kw., 250-volt, d.c. generators driven by 20-in. and 42x42-in. Allis Chalmers cross compound Corliss engines. All engines exhaust into one common barometric condenser. No additional boilers were installed in the blast furnace boiler house at the time No. 3 furnace was installed, but due to the heavy load on these boilers four additional boilers were added in 1920, making a total of 20 464-hp. Stirling boilers in this house. The boilers are equipped with Foster superheaters located back of the last pass, and steam is delivered at 150 lbs. pressure and 125 deg. superheat.

In 1919 No. 1 blast furnace was reconstructed, making it a 500-ton furnace.

In 1922 No. 2 blast furnace was relined after having made a world's record for blast furnaces on a single lining. This furnace was in operation from September 24, 1913, to March 2, 1922, and produced 1,537,934 gross tons of iron.

In 1915 construction was started on Plant 2 steel mills. Ten 100-ton open hearth furnaces were installed, each equipped with a 488-hp. Babcock & Wilcox cross drum waste heat boiler. Each boiler has a Foster superheater and the boilers and superheaters are designed to deliver steam at 225 lbs. pressure and 200 deg. superheat. The induced draft fans are Green radial flow, driven by Terry steam turbines through Westinghouse reduction gears. In 1919 a 600-ton mixer was added to this shop. The mills consisted of a 40-in. reversing blooming mill and a 32-in. reversing break down mill and a 28-in. three stand three high structural mill.

The 40-in. blooming mill was built by McIntosh-Hemphill Company and is equipped with electric screw down and electric manipulators. The mill is served by five batteries of soaking pits, each battery with four 7 ft. 6 in. by 13 ft. pits. The pits are equipped with electric driven valve reversing and door pulling mechanisms and are fired by producer gas furnished by eight 10-ft. Hughes mechanical poked gas producers.

The 32-in. reversing break down mill was built by the Mesta Machine Company. It has electrically operated screw down and manipulators. The mill is served by four 19x50-ft. Laughlin continuous reheating furnaces equipped with cast iron recuperators. The furnaces are fired with coke oven gas. The furnaces and mills are so arranged that steel coming from the 40-in. mill can be passed through the furnaces or it can be transferred by the furnaces for direct rolling without reheating.

The 28-in. finishing mill was built by the Morgan Engineering Company. It is equipped with traveling tilting tables.

All three mills are electrically driven. The mills are so arranged that the three main drive motors are in one common motor room. The 40-in. blooming mill is driven by a 15,000-hp. reversing d.c. motor taking its power from a flywheel motor generator set, which is driven by a 3,000-hp., 2,200-volt, 25-cycle, 3-phase motor. The 32-in. mill and the 28-mill are each driven by a 7,500-hp., d.c. motor, taking their power from a common flywheel motor generator set which is driven by a 5,000-hp., 2,200-volt, 25-cycle, 3-phase, a.c. motor.

To drive the mill motors and auxiliaries two 5,000-kva. turbo-generators were installed equipped with surface condensers. To furnish d.c. power for lights and auxiliary motors, two 1,000-kw. motor generator sets were put in. All this power equipment was built by the Westinghouse Electric Company and it all was installed in the one motor room.

The steam for this power station was furnished by the open hearth waste heat boilers and a coal fired boiler plant located in line with the motor room. In the coal fired boiler house were installed three 1,076-hp. Springfield boilers, each equipped with 12-retort Taylor underfeed stokers and Foster superheaters. Like the waste heat boilers, these boilers deliver steam at 225 lbs. and 200 deg. superheat. The boilers receive 75 per cent condensate return, leaving 25 per cent raw water make up. This power station was connected up electrically on the a.c. system with Plant 1 a.c. station and on the d.c. system with the d.c. station at the blast furnaces.

Inland Blast Furnace No. 2

World's Record Production On Lining

Blown in September 24, 1913

Blown Out March 2, 1922

Total Days Operated 2,925

Total Iron Produced 1,537,934 Tons

Average Daily Production 528.8 Tons

Coke Consumed per Ton Pig 1918 Lbs.

Grades of Iron Produced

Basic	1,345,154 Tons
Foundry	159,965 Tons
Malleable	32,815 Tons
Total	1,537,934 Tons

Total Ore, Cinder and Scale Smelted 3,037,917 Tons

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In 1921 a rail finishing mill was installed in connection with the 28-in. structural mill, also a splice bar and hot tie plate department. At Plant 1 the 90-in. sheared plate mill was changed to a 100-in. sheared plate mill and an additional stand of rolls with tilting tables was added, making it a tandem mill. The added stand, which handles the finishing passes, is driven through a rope drive by a 3,000-hp., 2,200-volt motor. To reheat the slabs for the tandem mill two Laughlin continuous reheating furnaces were added, making a total of five furnaces for the tandem mill. These furnaces are fired with pulverized coal.

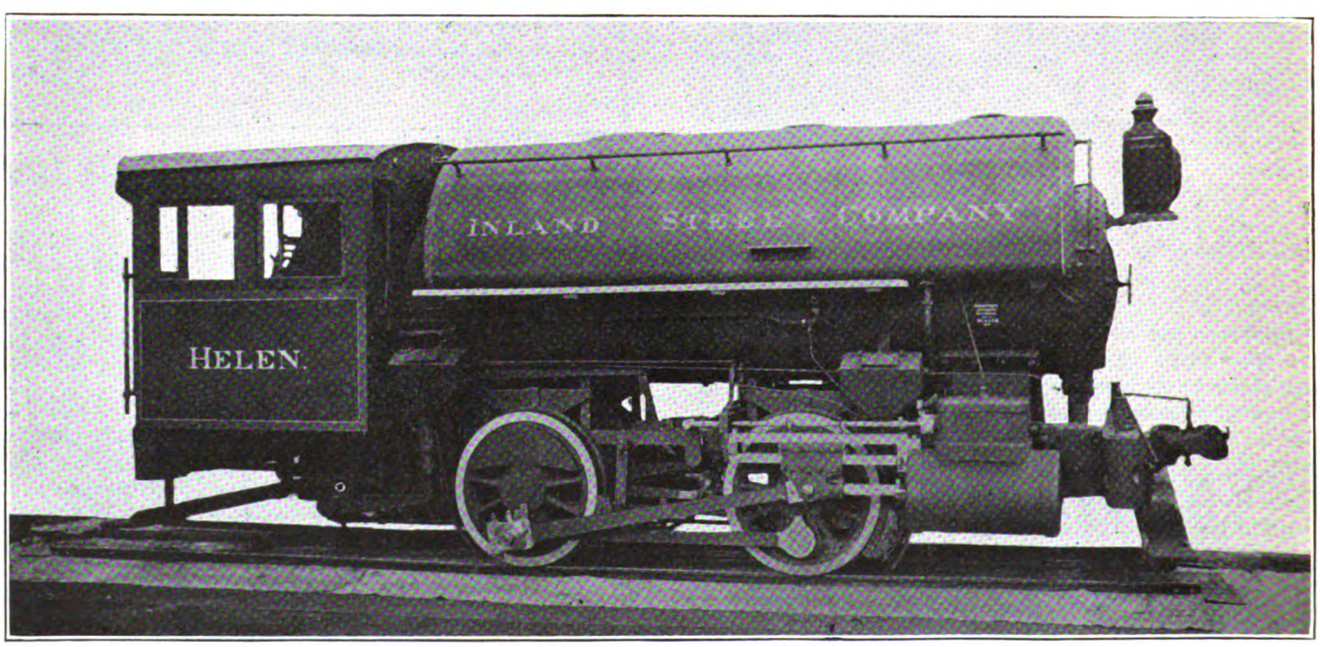
To furnish the additional a.c. power needed, a 12,500-kva. Westinghouse turbo-generator was added to Plant 2 power station. For additional a.c. power, one 1,000-kw. mg. set was installed at Plant 2 motor room and two 1,000-kw. mg. sets at Plant 1 d.c. substation.

At the Plant 2 steel mill boiler house, three 1,076-hp. Springfield boilers were added, making six 1,076-hp. boilers in this house. One of the new boilers was equipped with a 12-retort Taylor stoker the same as the original three, while the other two boilers were equipped with Coxe forced blast chain grates for burning braize.

The pulverized coal preparation plant for the tandem plate mill furnaces is located in an extension to the Plant 1 boiler house building. The raw coal is dumped from the cars into a 500-ton storage bin under an extension to the boiler house high line. From the raw coal storage bin the coal is drawn into a 30-in. belt conveyor, located in a tunnel under the preparation plant floor, which delivers the raw coal to a 50-ton bucket elevator which elevates the coal to the overhead crusher room. From the discharge of the elevator the coal passes through a 30-in. Jeffrey single roll crusher which crushes it to ¾-in. size. From the crusher the coal is carried by a short belt conveyor over a magnetic pulley for removing tramp iron and falls into two 65-ton crushed coal storage bins located over the inlet ends of two 15-ton Ruggles Coles hand fired rotary dryers. The coal is fed from the storage bins into the dryers by adjustable speed screw feeders. From the dryers the coal is dropped into a bucket elevator which delivers it to an overhead screw conveyor which in turn delivers it to four 3-ton dried coal feeder bins, located over four 5-roller Raymond pulverizers. From the pulverizers the coal is delivered by the air separators to two 5-ton pulverized coal storage bins located above the two 5-ton blow tanks which rest on platform scales, enabling the operators to weigh all coal pulverized and delivered to the furnaces. The Quigley transport system is used by which the pulverized coal is delivered with compressed air from the blow tanks to five 25-ton storage tanks located in front of the five continuous reheating furnaces at the plate mill. The coal is transported for a distance of approximately 600 ft. through a 4-in. pipe.

When the Plant 2 steel mills were installed, a new central pumping station was erected at the southeast corner of Plant 2. This station takes its water direct from Lake Michigan through an open sheeted flume 15 ft. wide. The water flows into this flume from the lake through 191 ft. 8 in. of loose stone filled pier with removable screens on the flume side of the pier. This method of construction was used to eliminate trouble from fish and needle ice, and so far it has been entirely successful. The flume leads from the intake into the pumping station and through the center of the building. The pumps are all motor driven centrifugal and are set in a line on both sides of the building, taking their suction direct from the flume. In this station are general service pumps having a total pumping capacity of 92,600,000 gallons of water.

(To be continued)



A view of one of the eight H. K. Porter industrial locomotives in service at Indiana Harbor. This is a four-wheel connected saddle tank machine, weighing 98,000 lbs, cylinders 16 in. x 24 in., built 56½ in. gauge on 46 in. drivers; operating boiler pressure 175 lbs., 19,900 lbs. tractive force; designed for special low head room 11 ft. 0 in. Transportation assumes railroad operating properties in a steel plant moving a million tons of coke and coal, over a half million tons of iron and over a million tons of ingots and finished steel per year. Twenty-eight locomotives are constantly employed, and are maintained in good condition at the adequate shop repair and machine shops of the plant.

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CURRENT TECHNICAL DIGEST

Developments in the Electrical Industry During 1923

A Digest of General Electric Company Accomplishments Important to the Steel Industry

By JOHN LISTON*

THROUGHOUT the electrical industry the year 1923 was characterized by a record volume of production in practically all classes of apparatus, exceeding in many cases the maxima of war time output. The demand for electrical apparatus showed seasonal irregularities, but manufacture proceeded almost uniformly at a high rate.

High pressure production is not unusually conducive to radical changes in design and a considerable proportion of the improvements made were along conventional lines. There were, however, a number of distinctly new developments which represented advances in the art, some of which were fully commercialized, while others were still being subjected to experimental test at the close of the year.

The recent tendency toward increased unit capacity continued in evidence. The 62,500-kva. turbine-generator, the first of the two 65,000-kva. waterwheel generators, and a synchronous converter of record size were completed, while various types of transformers exceeded the record unit ratings of previous years.

In transportation, electric propulsion was for the first time applied to large cargo craft for canal service and improvements were made in auxiliary ship equipment. The more important railway developments occurred in foreign countries as in the preceding year, and the high voltage d.c. system was utilized to a large extent for main line steam railway electrification. In street railway service there was a further adoption of the economical light weight double truck car.

The use of automatic stations was extended to new industrial fields and initial foreign installations were made. Few radical changes occurred in either the design or construction of the equipments, but the number installed and their unit capacity were greatly increased.

Higher efficiencies were achieved in the design of several types of industrial motors as compared with previous practice and corresponding advances were made in the control apparatus to be used with them. The vast number of motor applications in modern industrial plants renders every detail improvement secured in the operation of individual motors of great potential economic value when considered in the aggregate.

As in previous reviews, the electrical apparatus referred to are products of the General Electric Company, but reference to their development serves as indication of the tendencies in design and construction as well as the general trend of progress in the electrical manufacturing industry as a whole.

Turbines.

Developments during the year on large turbines consisted of refinement in mechanical details without radical changes in construction. The outstanding features were the production of turbines for high steam conditions and the production of turbines in unprecedented volume.

Shipments for 1923, exclusive of turbines for mechanical drive and ship propulsion, had a total capacity of approximately 1,660,000 kw. This was an increase of 85 per cent over the average for the preceding five years and an increase of 32 per cent over the maximum war time production in 1917.

The first of the 35,000-kw. turbines designed for 550-lb. pressure and 750 deg. F. total steam temperature was completed and shipped, while four of the same capacity and one 60,000-kw. compound unit to operate under similar steam conditions were under construction. It is confidently expected that the installation of these units will result in a substantial reduction in operating costs as compared with previous practice.

The solution of the problem of lower operating costs is being approached in two other ways. The first commercial equipment, which includes a mercury boiler and turbine exhausting into a condenser boiler which in turn generates steam for an existing steam turbine station, was put in service in the fall of 1923. The results which have been obtained confirm experimental tests and there is every reason to believe that this development will be of great value in reconstructing many existing stations.

In addition to this there were under construction one 2,600-kw. and one 4,000-kw. turbine designed for a

*General Electric Company.

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steam pressure of 1,000 to 1,200 pounds and to exhaust into headers supplying other turbines at from 250 to 350 pounds. These machines are an entirely new departure and involve special boiler equipment. The turbines, however, are simple in design and present no obstacles to the ultimate success of the system adopted.

Electric Propulsion.

Diesel-electric propelling equipments were adopted for two ships of a new type, built for refrigerating cargo service on the Great Lakes and New York State canal system and for coastwise trade to the West Indies during the winter. The first of these ships, the "Twin Ports," 258 ft. overall and 42 ft. beam with a full load draft of 13 ft. and a cargo capacity of 2,600 tons, started commercial operation in September.

The electrical equipment comprises two 250-kw., 230-volt, 260-rpm. d.c. generators direct driven by two Diesel engines and two 250-hp. motors direct connected to twin propeller shafts which give a speed of 13 miles per hour at full motor load.

Electric Railways.

As in the preceding year the more important additions to main line electrification occurred in foreign countries and it is noteworthy that in a majority of cases the 3,000-volt d.c. system was adopted.

Progress included the initial operation of 3,000-volt equipment on the Spanish Northern Railway in Spain, six locomotives having been made ready for service during the latter part of the year. Two substations were also completed for supplying 3,000 volts direct current for operation of this line.

Ten 150-ton, 3,000-volt locomotives for the Mexican Railway Company, Ltd., were completed and tested together with substation equipment which will be ready for operation by the time the first locomotives are placed in service.

In connection with the extensive electrification program being put through by the Japanese Imperial Government Railways, two locomotives weighing 66 tons each were placed in service.

Rapid progress was made on the manufacture of equipment for the Paris-Orleans Railways in France. The 120-ton, 1,500-volt high speed passenger locomotive was completed and tested and gave every indication of exceeding without difficulty all of the requirements for which it was designed. Speeds of more than 81 miles an hour, for which this locomotive was guaranteed, were made, and its riding qualities at high speeds surpass those of any electric locomotive ever built.

Automatic Railway Substations.

The automatic railway substation continued to be popular with electric railways both in this country and abroad, as was evidenced by a growing tendency to make electric railway systems completely automatic by installing automatic control for all substation units.

At the close of the year there were 70 railroad companies using G-E automatic substations with 225 equipments aggregating more than 170,000 kw. in capacity either in service or under construction. There were 13 stations of 4,000-kw. capacity and above.

The development of water power sources received more attention than ever before because of the high cost of fuel and labor and the need of additional sources of power to meet the needs of electrical expansion. Before the advent of the automatic station it was usually uneconomical to develop the water power sites of small capacity because of operating costs, but these small sites are coming rapidly into prominence, and automatic hydro-electric stations are now operating or being installed in nearly every state in the Union.

The largest single unit automatic hydro-electric station in the world is being installed by the Adirondack Power & Light Corporation for their Sprite Creek development near Little Falls, N. Y. It is rated 7,500 kva., 6,000 volt, 3 phase, 60 cycle, the largest previous equipment of this kind being of 5,000 kva. capacity.

The use of automatic substations in mining service was very decidedly increased and has fulfilled a real need in this particular field, where trained operators are scarce and many comparatively small installations are required to meet operating conditions, and where the power output must be reliable.

Waterwheel Generators.

The first of the two 65,000-kva., 12,000-volt, 25-cycle, 107-rpm. whaterwheel generators for the Niagara Falls Power Company was completed and shipped in sections to the power site for assembly. It is the largest machine of its type, both in capacity and physical dimensions, so far constructed.

Frequency Converters.

A frequency converter of exceptional capacity and unusual characteristics was constructed for tying together the 25 and 60-cycle systems of the United Electric Light & Power and the New York Edison Companies.

The induction type unit will supply 150,000 kva. to the 60-cycle system with a short circuit on the 60-cycle bus and with 25-cycle bus voltage maintained. In the reverse direction, it will supply 191,000 kva. to the 25-cycle system with 60-cycle bus voltage maintained. The induction unit will be excited from the 25-cycle synchronous generator and the set is designed for unity power factor, input and output in either direction at full load.

The kw. capacity of the set is nearly three times that of the largest frequency converter previously built, and marks a new epoch in the construction of horizontal shaft a.c. machines.

Industrial Motors.

The single-phase motor is an important factor in many industrial applications, but early designs had certain electrical and mechanical characteristics which tended to limit the field of its practical utility. A new type single phase motor which operates on the squirrel cage induction principle was developed which eliminates entirely the short circuiting switches heretofore considered essential and permits the simplest possible construction.

A complete new line of 40-deg. continuous duty riveted frame polyphase motors, in sizes up to 15 hp., was designed with numerous improved electrical and mechanical characteristics as compared with previous construction for this class of motor.

During the year considerable work was done towards standardizing the bores of small high speed motors used generally by the wood working trade. Through the efforts of several of the electrical companies, most of the tool manufacturers are now using

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a definite bore for these shaftless motors. Before this standardization, there were a great many different bore dimensions for the same frame, which was decidedly objectionable from a manufacturing standpoint.

Industrial Motor Control.

A number of improvements were made in the apparatus designed for the control of industrial motors which, despite the relatively small size of the individual controller, are of great economic value due to the vast extent of the field of present day industrial motor application.

Among the more important of the new designs is a starting switch for 3-phase motors, size up to 7½ hp., 440 and 550 volts, which is of the positive quick-make and quick-break tumbler type, totally enclosed with the operating handle on the front and a locking plate on the side so that it may be locked to prevent either the opening of the box, the enclosing of the switch, or both.

An ingenious design of a magnetic switch provided with a thermal overload relay, was developed to meet the demand for starters of compact construction and for mounting in the frames of machines. It is suitable for motors up to 10 hp., 550 volts, 25 to 120 cycles, and the units can easily be arranged on panels so as to insure complete control at any point desired of machines driven by two or more motors of either the same or different ratings.

Motor Applications.

To meet the requirements of the Russian government in regard to electrical equipment for oil well drilling, two totally enclosed induction motors were developed, rated 75 hp. and 50 hp., 750 rpm., with a temperature rise of 45 deg. C. These motors are unique in that they are the largest totally enclosed, self ventilated motors yet manufactured, previous designs in these sizes having employed water as a cooling agent.

The H. C. Frick Coke Company is installing a belt conveyor approximately five miles long for transporting coal from the mine workings to the shipping station. It consists of 20 sections, each driven by an induction motor. The motors vary in size from 50 to 175 hp. and are all of the wound rotor type. Solenoid brakes are provided for stopping and holding the conveyor belts when power is cut off from the motors and the control is so arranged that the motors start in sequence beginning at the delivery end. As each motor reaches full speed, it energizes the starting circuit of the next succeeding motor. If any motor stops, it automatically stops all the motors preceding it in the conveyor system, but allows those following it to run and clear the belts of coal.

Electrical equipment was provided in 1923 for two d.c. coal tower hoists for the new Hudson Avenue Station of the Brooklyn Edison Company to give a hoisting rope speed of 1,460 ft. per minute, and a lowering rope speed of 1,680 ft. per minute, on the 200-ft. lift and to give a guaranteed delivery of 250 tons per hour, using a 2.5-ton grab. The hoist motor is rated 625 hp., is direct connected to the hoisting drums, and takes its power from a 575-kw. motor generator set mounted on the tower and driven by a 700-hp., 2,300-volt, 3-phase, 60-cycle induction motor.

Steel Mills.

There was added to the existing main roll drives, 300 hp. and over, 44,100 hp. (normal continuous rating), bringing the total to 612,110 hp. The tendency towards the use of high speed motors with reduction gears, which has been quite marked for the last few years, continued to gain headway, and over 90 per cent of the new motors were for geared drive.

One of the most important developments of the year was the building of a.c. brush-shifting motors with shunt characteristics. Two machines of this type, which gives adjustable-speed without auxiliary apparatus, were under construction for the Halcomb Steel Company, Syracuse, N. Y., for driving merchant mills, and are rated 600-400-200 hp., 321-214-107 rpm., 440-volt, 25-cycle and 500-385-250 hp., 130-100-65 rpm., for the same power supply. There has long existed a need for an adjustable speed a.c. motor that was simple and did not require a large amount of auxiliary equipment, and whose speed would be practically independent of its load. This machine is the first practical piece of apparatus to meet these requirements.

Induction Furnaces.

The new type of induction furnace, which utilizes the force of electro-magnetic repulsion existing between transformer primary and secondary windings, to cause a circulation of molten metal between the heating circuit and the melting pot, was operated only experimentally during 1922.

Fifteen 75-kw., 1,200-lb. induction furnaces were placed in commercial operation for melting non-ferrous metals in 1923, and a number of additional units were under construction.

A notable accomplishment of the repulsion-induction furnace was the successful melting of pure copper on a commercial basis.

Industrial Heating.

The electric furnace was for the first time successfully used for the bright annealing of copper wire.

Another special furnace was developed for annealing steel punchings used for field and armature laminations. It is built 6 ft. above the floor on a structural steel support and the laminations are placed on a car which is rolled under the furnace and raised into the heating chamber on a hydraulic platform. Around the edge of the car is a sand seal which makes the furnace air tight when the car is in place.

Transformers.

The recent tendency to concentrate the transformation of electrical energy in units of increasing capacity was evidenced by the construction of a large number of transformers of record size. A notable event of the year was the placing in service of the 220,000-volt units at Power House No. 8 of the Southern California Edison Company's system, from which approximately 20,000 kw. was initially transmitted to Eagle Rock substation near Los Angeles.

There were under construction two self-cooled, three-phase, 60-cycle units which will transform 15,000 kva. as auto-transformers from 72,000 volt Y to 132,000 volt Y with solidly grounded neutral. Both of these windings will have taps. They will also transform 15,000 kva. from either of the high voltage windings to 12,470 volts and simultaneous operation on all three windings is possible. These transformers are larger in physical dimensions and in kva. rating than any self-cooled transformers heretofore built, the largest previous rating being 12,000 kva.

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Seven 60-cycle, 10,417-kva., single-phase, self-cooled auto-transformers of unusual construction were built for the Brooklyn Edison Company. They step up the generator voltage from 13,800 volts to 27,600 volts and have a normal rating of 10,417 kva., but since they are auto-transformers of a 1 to 2 ratio, each will transform a total of 20,834 kva., so that the total output of a bank of three units will be 62,502 kva. This is probably the largest amount of energy transformed by a single bank of self-cooled transformers.

The maximum capacity for single-phase, water-cooled transformers was increased by the construction of 10 units, rated 22,000 kva., 39,500-68,500-2,300 volts, 25 cycles for the Niagara Falls Power Company.

A three-phase air blast transformer exceeding all previous units in both capacity and physical dimensions was built for the New York Edison Company. It is rated at 17,100 kva., 11,800-2,950 volts, 25 cycles.

There was further demonstration of the value of concentric circular windings for extra high-voltage transformation. The marked advantages of this type over the oil interleaved (sandwich) type had been brought out in studies of impressed high-voltage transients on commercial transformers, this work being carried on in the high-voltage laboratory. The unique equipment of this laboratory has placed high-voltage transformer design on a scientific basis heretofore unattainable and has made possible the absolute checking of calculated phenomena. The same studies also advanced the use of the "built in" protective devices.

An unusual arrangement of instrument transformers was provided for metering energy on the high potential side of substations on the Paris-Orleans Railway. Four 60,000-volt transformers each have three current and two potential transformers, while two 90,000-volt units have three each of current and potential transformers mounted in a single tank with three high-voltage leads.

The 90,000-volt arrangement is unique in that the three current transformers are located inside the porcelain bushings, whose headers also serve as oil conservators.

The average unit size of self-cooled transformers continued to increase, but due to specific conditions the average for all types was somewhat reduced as compared with 1922. Table A shows the average rating for the past five years:

TABLE A

AVERAGE UNIT SIZE OF POWER TRANSFORMERS IN KVA.

Year	Self-Cooled	Water Cooled	All Types
1919.....	1175	4325	2150
1920.....	1325	3175	2175
1921.....	1575	4150	2750
1922.....	1700	6000	3750
1923.....	2350	5125	3220

At the close of the year there had been completed or were under construction a total of more than 180 units of 10,000 kva. or above.

Induction Voltage Regulators.

A new design single-phase induction voltage regulator was developed, which embodies a number of improvements as compared with previous types. In addition to improving the voltage regulation by a more rapid correction of voltage changes, it utilizes a tank which is highly resistant to rupture as a result of explosions, and a rigid internal mechanical structure to minimize noise during operation. An improved method of bracing the coils prevents insulation troubles due to line short circuits.

Lightning Generator.

The lightning generator installed in the High Voltage Laboratory of the Pittsfield Works will produce voltages of approximately 2,000,000 above ground. This is perhaps higher than lightning voltages that are usually produced on transmission lines. These voltages are of a known wave shape and duration. The wave front is under control and may be made so steep that the voltage starting at line voltage may be made to increase at the rate of 50 million million volts per second. The rate that energy is dissipated in the arc is generally of the order of millions of horsepower. The duration of such discharges is conveniently measured in micro-seconds (millionths of seconds).

Conductor Cable.

As the result of exhaustive research work, the manufacture of 66,000-volt single conductor cable was for the first time placed on a commercial basis.

The cable produced was for the Cleveland Electric Illuminating Company and can transmit upwards of 33,000 kw. at 66,000 volts. It is slightly over three inches in diameter and requires 125,000 volts to puncture.

The previous maximum potential for conductor cable in the United States was 44,000 volts; cable of this rating being utilized for the underground circuits of the New York Edison Company.

High Voltage D.C. Current Cable Testing Sets.

The purpose of d.c. testing sets is to permit power companies to make satisfactory periodic test of underground cables, to determine the condition of insulation between conductor and ground and to locate cable faults and measurements of insulation resistance. Three types of equipment were developed and standardized for this service.

For station use, to be considered as a stationary outfit, a four Kenotron 200,000-volt set was designed, each Kenotron being capable of rectifying 250 amperes d.c.

For cable testing this set is used in the following manner: During one-half cycle the current flows through two Kenotrons in series and charges one conductor, during the other one-half cycle current flows through the other two Kenotrons and charges the other conductor with the reversed polarity, so that the voltage between the conductors will be twice the crest value of the transformer voltage. The voltage across the two Kenotrons in series on the reverse wave will be the transformer voltage plus the voltage from the conductor to ground, which will be a maximum of 200,000 volts.

The d.c. voltage is measured by special meters which measure the crest value of the voltage wave obtained from the voltmeter coil. Two meters are used, each meter reading the voltage from conductor to ground and the voltage between conductors is the sum of the two readings of the voltmeters. The current supplied to the cable is measured by two ammeters connected between the ground and the transformer winding. In series with each meter is a tungar rectifier which divides the current so that one-half

(Continued on page 57)

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Engineering Achievements

Westinghouse Developments of Interest to the Steel Industry During the Year 1923

By H. W. COPE*

THERE have been presented to the world in the past year, by the Engineering Staff of the Westinghouse Electric & Manufacturing Company, developments and achievements in the electrical art, which not only compare favorably with those of former years, but are of a character that will wield a lasting influence on the world's progress.

The need for better transportation facilities throughout the world, and especially in the United States, has been provided for in part by development and construction work which has been in progress throughout the year, the completion of one important foreign steam railroad electrification, and extensive additions to electrifications in the United States.

The year 1923 has witnessed the beginning of the engineering and construction on one of the world's most gigantic steam railroad electrifications, namely, that of the Virginian Railway, from Mullens, W. Va., to Roanoke, Virginia.

Each year witnesses the extension of the useful field of electricity, not only to new kinds of work which it can better perform, but to its more general use in proven fields. The growing demand for electrical equipment for transportation, industry, agriculture and the home necessarily increases the requirements in the field of generation, transmission and distribution to meet the increasing power demands.

The construction of new generating stations employing units of tremendous capacity and the extension of other stations to provide greater output have taken place during the year. The consolidation of systems, forming great networks, insuring even greater reliability in energy supply by interchange of power has continued.

The marvelous broadening of the useful field of radio in intellegience transmission continues with rapid strides. This new system of disseminating information by broadcasting concerts, lectures, sporting news, market quotations, etc., has come to be one of the nation's established activities.

Generation, Transmission and Distribution of Power.

The art of design and construction of electrical equipment for the generation, transmission and distribution of power in the great systems of today has kept abreast of the growth in size of these systems. Each year brings with it the phenomenal growth of these power systems and attendant problems to be solved.

Turbine-Generators.

The size of generating units continues to increase year by year. It is worthy of note that a 62,500 kva. steam turbine generator, the largest single unit of this type in all the world, is being installed. A 43,750 kva., 1800 rpm. machine under construction is the largest steam turbine generator of this speed ever built. There is also under construction a 62,500 kva. cross compound unit, consisting of one 25,000 kva. generator and one 37,500 kva. generator.

At this time a 62,500 kva. cross compound unit consisting of two 31,250 kva. generators is being built. In connection with both of these cross compound units and other large single generator units there has been developed direct-connected 1800 rpm. a.c. generators for direct connection to the main turbine, constituting an independent source of power for electrically driven auxiliaries. This is a new development in power station design, these direct-connected a.c. generators replacing separate turbine generator units.

During 1922 there were placed in service 32 turbine generator units varying in size from 3,750 kva. to 43,750 kva., totalling 427,150 kva. For the first 10 months of 1923 contracts have been received and the company now has in process of construction and installation 82 units (3,750 kva. and larger) totalling 1,644,235 kva. The number of large units that will be placed in service in 1923 and 1924 will exceed all previous records of the company.

The first multipath ventilated 30,000 kva. single cylinder turbine generator unit was put into operation during the year.

Water Wheel Generators.

The hydro-electric generating station occupies a very advantageous position in the production of electric energy at low cost. This year has witnessed the beginning of operation of Big Creek No. 3 Station of the Southern California Edison Company, containing three (3) 28,000 kva. 428 rpm., 50 cycle vertical generators. This installation is notable in that these are the largest generators built for such a high speed and are now operating with gratifying success. These machines are also designed for 60 cycle operation at 514 rpm. which is exceptionally high speed for a machine of this capacity. At the guaranteed 85 per cent over speed the peripheral speed of the rotor is five miles per minute. This is the largest hydraulic generating station west of the Mississippi River. Other orders of special interest are:

Two 15,000 kva. 95 rpm. generators.
Two 12,000 kva. 133 rpm. generators.
Four 4,500 kva. 100 rpm. generators.
Three 6,660 kva. 500 rpm. generators.
Two 6,250 kva. 300 rpm. generators.
Two 10,000 kva. 200 rpm. generators.

Frequency Changers.

There has recently been installed the world's largest frequency changer. Its rating is 35,000 kw., generator output, at 100 per cent factor. The set is driven by a 47,800 hp. motor which receives its power from a 13,800-volt, 3-phase, 60-cycle supply. The length of the set is 47½ feet, the width 20½ feet and the frame diameter of the largest unit is 18 1-3 feet. The set

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weighs 440 tons and both units are totally enclosed. Other orders of interest are:

Three 7,500 kva. 600 rpm. set.
Two 5,000 kva. 750 rpm. sets.
One 15,000 kva. 300 rpm. set.
One 7,500 kva. single phase set.

During the year the company has completed the development and installation of a number of devices for shifting the stators of machines used as parts of frequency changer sets. Its use makes it possible to shift the phase angle in such a manner that an unloaded set may be synchronized exactly with the line and also to control the load division between sets operating in parallel.

Synchronous Condensers.

Synchronous condensers for voltage control at the receiving end of long high voltage transmission lines and for power factor correction are in demand by the power companies as evidenced from the following recent installations or construction in progress:

Three 30,000 kva. 600 rpm. synchronous condensers.
One 10,000 kva. 600 rpm. synchronous condenser.
Three 5,000 kva. 750 rpm. sychronous condensers.
Two 5,000 kva. 720 rpm. synchronous condensers.
One 15,000 kva. 450 rpm. synchronous condenser.
One 10,000 kva. 720 rpm. synchronous condenser.
One 10,000 kva. 720 rpm. synchronous condenser.
Two 5,000 kva. 720 rpm. synchronous condensers.
One 12,500 kva. 720 rpm. synchronous condenser.
Two 10,000 kva. 720 rpm. synchronous condensers.
One 15,000 kva. 600 rpm. synchronous condenser.
One 10,000 kva. 720 rpm. synchronous condenser.
One 15,000 kva. 600 rpm. synchronous condenser.
One 7,500 kva. 720 rpm. synchronous condenser.
One 12,500 kva. 720 rpm. synchronous condenser.
Two 7,500 kva. 720 rpm. synchronous condensers.

Synchronous Converters.

An important improvement has been made in the design of large 60-cycle booster synchronous converter used in lighting service by introducing the use of high reluctant poles. These were first used on high voltage converters for railway service. During abnormal conditions involving reverse current, commutation is improved.

Synchronous Motors.

A new type of damper winding for high speed synchronous motors, condensers and generators has been developed which, in addition to simplifying the construction makes the machine capable of successfully withstanding much higher over-speeds than formerly.

Three high speed 650 hp. 3600 rpm. synchronous motors for driving multiple stage steam turbine type air compressors have been built. A 1700 hp. 1500 rpm. synchronous motor has also been built.

The use of motor driven gas compressors has been extended through the development of an enclosed type of collector to prevent the possibility of sparking at the brushes igniting the gas. This has been accomplished by totally enclosing the rings in a sheet steel drum through which air is forced by means of a separate motor driven blower.

Motor Generator Sets.

A large number of motor generator sets of various types have been constructed during the year.

One of the unusual designs executed is that of a very high frequency single phase motor driven generator for supplying power to an induction furnace producing special steel alloy. This generator has a rating of 100 kw. 5000 to 7000 cycles and 125 to 250 volts. It is driven by a d.c. motor connected through high speed gearing. The design of this generator was difficult due to very high frequency and high speed. As an indication of the nature of the problems met in this design, it was necessary to take into account in the magnetic calculations the decrease in the size of the air gap caused by the increase in diameter of the rotating parts resulting from rotational forces.

Automatic Control of Generating and Substations.

The extension of automatic control of generating and substations is continuing at a rapid rate. New features have been added to this equipment which broaden its field of application and make for even greater reliability.

There is under construction now the largest single automatically controlled converting unit built to date consisting of a 3,750 kw. three-machine, automatically controlled, motor generator set.

Complete automatic and supervisory control equipment for two 4000 kva. water wheel driven generators is under construction. This will be the largest automatically controlled generating station in existence.

There are in operation in St. Louis two 1800 kw. automatically controlled synchronous motor generators. The application of automatic substation control to large areas of large cities is continuing with remarkable success.

Automatic substations for coal mines and industrial plants have been installed in great numbers.

One of the largest installations of automatic control is now being executed in Japan. A 4000 kw. 1500 d.c. automatic substation consisting of the automatic control of two 2000 kw. synchronous converter sets and transformers for the Imperial Government Railways of Japan is being installed.

One of the outstanding achievements of the year is that of developing electro-pneumatic switching equipment for automatic switching service in railway substations. The electro-pneumatic type of switch has contributed to the great success of Westinghouse multiple unit railway control. Simplified control circuits, greater interchangeability of parts and reduced space requirements result from the use of this type of equipment.

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Supervisory Control.

By taking advantage of the wonderful development in machine telephone switching, the Westinghouse Company has perfected application of the principles and devices of that art to the distant control of all types of power and switching devices. A single operator in a central location may have complete control of the generation of power and its distribution over a large system. By means of simple, small, colored lamp indicators, he has at all times, complete information concerning the operating status of the entire system. Through the medium of small control keys he performs in a distant station all of the operations usually performed by an attendant. A simple two or three wire telephone circuit is the only physical connection between the dispatcher and the unattended station. Many equipments of supervisory control have been installed during the past year and the limit of its possibilities is not yet in sight.

The advance of automatic and distant controlled unattended stations, while wonderfully successful in operation, left something to be desired. The dispatcher could not determine the load at such stations. To make this possible, several very simple and efficient means of remote metering have been perfected. Making use of the same metallic circuit as used for the supervisory control, the dispatcher receives a continuous indicating, graphic recording, integrating and graphic demand record of the load at any point. Regardless of the source or whether the load record received is of a.c. at 25 to 60 cycles or d.c., all indications may be totalized through one instrument to read the total simultaneous load and demand on an entire power system. These systems, several of which are now in operation, are free from resistance errors common to earlier schemes of remote metering.

The successful development of automatic and supervisory control has greatly extended the range of natural power sites that may be profitably developed. This is especially true of small power sites which, if developed and manually operated, would produce power only at a loss. Automatic control by making attendance unnecessary turns the loss into profit. At natural power locations on streams and rivers remote from inhabited areas and difficult to reach or surrounded by conditions unsatisfactory to continued habitation, automatically controlled stations solve the problem. Means of performing all operations ordinarily entrusted to an operator are performed with greater precision, even to actual synchronizing by automatic means.

All Westinghouse automatic substations at both Cleveland and Baltimore are provided with supervisory control and systems of remote load indication.

Transformers.

The phenomenal growth of the great power systems of this as well as other countries requires the raising of transmission voltages to values which are unprecedented and demands the design and construction of transforming equipment of greater voltage ratios. Factory and field testing of equipment for these extremely high voltages requires the construction of testing equipment of much greater voltage range.

The first 220,000 volt transmission lines for commercial service were put into operation in May of this year by the Southern California Edison Company. There are in successful operation seven 18,750 kva. transformers and six 37,700 kva. auto transformers all of the shell form of construction.

The Southern California Edison Company and the California Institute of Technology are installing a 1,000,000 volt transformer outfit consisting of four 250,000 volt testing transformers for cascade connection. All of the units except the first are insulated from ground respectively at 250,000, 500,000 and 750,000 volts. Two complete 500 kva. regulating equipments are provided so that the units may be operated in open delta connection for 500,000 volts, 3 phase, or two independent single phase testing equipments can be obtained for operation up to 500,000 volts. This is the first equipment to be built for obtaining high voltage by a cascade arrangement. During the factory test of this equipment, the longest controlled electric arc ever witnessed in a testing laboratory was drawn.

The company has built and delivered a bank of transformers of the self-coolig type which have a maximum guaranteed continuous output of 56,000 kva. at 118,000 volts. Tests indicated that they would carry a load of 60,000 kva. within their guarantees. These are probably the largest transformers ever built which cool themselves without recourse to artificial means of cooling.

Seven 18,500 kva. transformers for raising the generating voltage of the Big Creek Station of the Southern California Edison Company to 220,000 volts were placed in operation in October. This is an important link in the Southern California Edison's projected power system which operates at the highest voltage yet attempted.

This year has seen the development of the "inertaire transformer," a unit in which an inert gas is introduced above the oil level to protect the oil against oxidation and to eliminate whatever fire risk or danger of explosion exists in a transformer. The inert gas is introduced automatically into the transformer case through the natural breathing of the unit, due to temperature changes. The air breathed into the case whenever the temperature falls, passes through a deoxidizing compound which abstracts the oxygen, leaving pure nitrogen to enter the space above the oil level. With no oxygen in contact with the oil, oxidation or sludging is prevented and not only is deterioration of the oil eliminated but also its quality actually improves with service due to the withdrawal and elimination of the oxygen dissolved in the oil. An explosion as nitrogen, and fire can not be started as the presence of oxygen is needed to support combustion.

Eight oil insulated forced-cooled locomotive type transformers rated at 2,350 kva. at 10,500 volts, 25 cycles and a 4,000 kva., 11,000 volt, 25 cycle unit of the same type have been constructed. These are probably the largest transformers yet built for this type of motive power.

Lightning Arresters.

A study of the phenomenon of glow discharge has resulted in the development of the autovalve arrester and the number of units sold and installed during the past year has been limited by production conditions solely. This arrester is rapidly displacing other types. All sizes, from those for secondary distribution circuits at 110 volts to those for the protection of the largest stations at 73,000 volts were manufactured. A

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few for voltages up to 132,000 volts have been constructed.

Switching.

The growth in size of generating units, power houses and the inter-connection of systems is rapidly increasing the duty requirements on switching apparatus. Not only is the amount of power that must be controlled increasing, but there is a demand for heavier duty cycles, and the requirement that apparatus must handle this large power much more effectively than heretofore. The hazards to an operating system involved by heavy short circuits are such that the utmost precautions must be taken to render phase to phase short circuits impossible and thus through new standard apparatus to limit phase to ground short circuits to small values by the use of neutral resistors. The outstanding development in this respect is the isolation of phases in the switch houses so that it is impossible to have phase to phase shorts at any point from the generator terminals through to the cable pot heads. The first large stations using isolated phases adopted the horizontal arrangement, but in the past year, practically all new layouts have been of the vertical arrangement. The Westinghouse Company has developed apparatus to meet short circuit requirements up to one and one-half million kva. for both types of arrangement.

Transmission.

In recent years increasing consideration has been given to projects involving the transmission of large blocks of power. To design such systems it is necessary to know the maximum power which can be transmitted taking into account the characteristics of the load and synchronous apparatus in combination with those of the line. Analytical methods for determining the power limits were developed and checked by tests on an artificial transmission system having a generating capacity of 650 kva. and operated at 2300 volts. The transmission line was built in two sections so that increase in the power limit of a line when an entermediate synchronous condenser station was added could be determined experimentally. The results of the investigation will be presented in a series of papers at the A.I.E.E. mid-winter convention.

Semi-tension construction for aluminum steel core cable is now being used. The new semi-tension and suspension clamps are designed for this type of construction and were used on the Skagit River development of the City of Seattle, Washington.

A new high strength suspension insulator has been developed which, for mechanical strength, surpasses anything yet produced.

Feeder Regulators.

The company built and installed this year the largest step type induction regulator ever constructed. This 250 kva. regulator together with a special 15,000 volt transformer ties together the 57,000 volt star bus of the City of Seattle with the 50,000 volt delta bus of the City of Tacoma system and permits the interchange of power between the two systems.

Some large regulators designed during the year were:

Three 1000 kva. 4160 volts, 3 phase, 60 cycle.
Three 750 kva. 5000 volts, 3 phase, 60 cycle.
Five 260 kva., 7500 volts, 30 cycle.

The most noteworthy feature in connection with the feeder regulator work is that of the increasing demand for this type of equipment.

Steam Turbines and Condensers—
Large Turbines.

The company's engineers at its South Philadelphia Works have finished the engineering development of the new 20,000 kw. and 30,000 kw. turbines in which there are embodied a number of novel features. These frames are designed for the above ratings with the higher steam pressures, superheat and vacuum prevailing in most modern stations today. Under certain conditions, an overload of 25,000 and 35,000 kw. respectively, can be obtained on the tertiary valve.

Considerable time has been spent on the study of a turbine for 1,200 pounds steam pressure and final designs are now in progress. This will be a reducing turbine having an exhaust pressure of 300 pounds gauge, which condition led to the development of a special high pressure gland, known as the boiler feed pump type of gland, wherein condensate from the main condenser is used as sealing water. The gland acts as a stage heater and retains in the system most of the heat which would otherwise be lost through friction and condensation in the gland.

After complete studies and the preparation of many designs for a single cylinder type of 50,000 kw. turbine for standard operating conditions of 325 pounds, 200 deg. superheat, and 29-in. vacuum, it became obvious that machines of this size should be built as cross compound units with elements running at 1800 rpm. rather than a single 1200 rpm. unit.

A single cylinder unit involved a rotor weight of 120 tons and precluded the possibility of shipment without taking the rotor to pieces.

A 50,000 kw. unit has been designed as a three-cylinder machine, the high pressure and intermediate pressure elements being connected tandem to one generator and the low pressure element being a double flow machine driving a generator, all elements running at 1800 rpm. One novel feature of this unit is the use of twin vertical surface condensers, one on each side of the machine, with their upper water boxes above the engine room floor. The steam leaving the high pressure turbine is conducted to the boiler room and reheated to 700 deg. F. before entering the intermediate pressure element and many special problems were introduced by reason of the high temperatures resulting from this arrangement. After careful study the high pressure and intermediate pressure elements were separated so that they might expand freely. On account of the comparatively large volume in the reheater and its connected piping containing steam no longer under control of the regular turbine governor, special arrangements for governing are required to prevent the turbine overspeeding in case of a sudden large reduction in load. As this machine is designed for 600 pounds initial steam pressure, special pipe flange standards are necessary.

The designs are well under way for a new 15,000 kw., 1800 rpm. turbine. This frame will also have modifications to take care of 1500 rpm. installations.

As a further result of the balancing machine development carried on at the South Philadelphia Works, a 125-ton balancing machine has been built and installed at the East Pittsburgh Works. This balancing machine is a substantial duplicate of the large

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machine designed, built and installed at the South Philadelphia Works.

Condensers.

An improved line of unit type condenser of up to 4000 sq. ft. was manufactured wherein the pumps are more efficient and accessibility for inspection or repair has been increased.

Feed water heaters were also developed for use in feed heating systems wherein steam is extracted from the main turbine for heating the feed water.

Among numerous other condensers there have been built two 70,000 sq. ft., single shell, a size which we believe has not been exceeded anywhere.

A new design of centrifugal circulating pump having large capacities was developed. This pump has specially designed suction passages and shows a remarkable efficiency.

Hotwells for use on surface condensers have been developed wherein the excess oxygen contained in the condensate is reduced to practical elimination.

As a result of studies and experimental investigation the economy of air ejectors has been improved.

Small Turbines.

The design and development has been completed for a 1½ kw. generator set for industrial purposes.

Railways—Heavy Traction.

This has been a banner year for the company in the heavy traction field. Forty-one locomotives have been shipped during this period. There are also under construction equipment for 62 large motive power units which constitute all of the steam railroad electrification locomotive business placed during 1923 by the railroads of the United States. This indicates that the open minded policy of furnishing the type of equipment best suited for the conditions is correct as reflected in the company's business during the past year.

Our engineering recommendations have always favored the use of the a.c. system for heavy tonnage railroad electrification. Fifty-seven of the units under construction are to operate from a sigle-phase trolley. Among these are the Norfolk and Western and Virginian units for the most powerful electric locomotives ever designed or built.

Industry—Steel.

1. Among distinctive installations of electrical equipment for rolling mill drives made during the past year is the apparatus supplied for operating a 16-in. hot strip mill. The roughing stands of this mill are driven through herringbone gear units by two 1500-hp., 705-rpm. induction motors with liquid slip regulator control. The four finishing stands are arranged to form a continuous train, each stand being driven by a separate compound-wound 240-volt d.c. motor. Two of the motors are rated 1500 hp. at 125 to 250 rpm. and two are rated 1800 hp. at 165 to 350 rpm. These motors are designed with such close inherent speed regulation that they operate throughout their range without any automatic speed regulating control. This is the first installation of a drive for a continuous hot strip mill train which has been operated without special control for maintaining correct speed. Power for the d.c. motors is supplied by two synchronous motor generator sets each consisting of two 1000 kw. 600-volt generators and a synchronous motor.

2. Two 5000-hp., 370-rpm., induction motors were placed in operation. One motor drives a 90-inch three-high plate mill and the other a 132-inch three-high plate mill. Both motors replaced steam engines.

3. Notable among foreign orders is one covering complete electrical equipment for a blooming mill, a structural mill and a three-high plate mill. For the blooming mill a 5,000-hp., 700-volt d.c. single unit reversing motor operating from zero to 120 rpm. will be supplied. This will be the largest single unit reversing motor in operation. For the structural mill there will be a 3750-hp., 700-volt reversing motor having a speed range of zero to 150 rpm. These two motors will be supplied with power from a fly wheel motor generator set consisting of one 3500-kw. d.c. generator, one 3000-kw. d.c. generator, one 180,000-pound fly wheel and a 5000-hp. induction motor. A 3000-hp., 735-rpm. induction motor with herringbone gear unit will be supplied for the plate mill. Complete switchboard and control is included with the order together with motors and control for the mill auxiliaries.

4. Orders have been received for equipment to drive a 40-inch reversing blooming mill and a 48-inch universal plate mill. The equipment for the 40-inch blooming mill consists of a 7000-hp., 700-volt, 0-120-rpm. double unit reversing motor; a fly wheel motor generator set having two 3000-kw. generators, one 100,000-pound fly wheel and one 3750-hp. induction motor with complete switchboard and control. Both equipments will replace steam engine drives.

5. An order has been placed for equipment to replace engine drives on a 24-inch structural mill and a 22-in. bar mill. The 24-in. structural mill drive consists of a 3000-hp., 600-volt, 325-485 rpm., d.c. motor connected to the mill through a herringbone gear unit; a fly wheel motor generator set consisting of a 2500-kw. generator, 60,000-pound fly wheel, 2500-hp. induction motor, together with switchboard and control. A 2500-hp., 500-rpm. induction motor with liquid slip regulator control will be supplied for the bar mill drive.

6. The Company has on order a 1500-hp., 230-volt, 470-510-rpm., d.c. motor; a 1000-kw. synchronous motor generator set, a 75-hp. reel drive, and complete control to replace engine drive on the finishing stands of a rod mill. The control for this equipment has a number of special features. The roughing and intermediate stands of the mill are to be driven by the present engines the speed of which are subject to considerable fluctuation. To insure successful operation of the motor with the engines, automatic control will be supplied which will cause the 1500-hp. motor to follow the variations in the speed of the engines, thus preventing breakage of the hot steel rod or damage due to excessive looping. Automatic control is also included for the rod reel drive which allows the reels to take up the finished rod uniformly regardless of the speed of the mill.

Fans.

A new 36-inch ceiling fan has been developed.

Instruments.

The outstanding feature in instrument engineering was the announcement of an entirely new line of a.c. switchboard instruments working on the dynamometer principle and replacing the former well-known Westinghouse induction type. These new instruments contain many novel and interesting features which place

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them in advance of all other meters. In addition to the usual 7-inch type these are made as a complete line in a smaller case 4⅜ inches in diameter, in agreement with our engineering tendency to recommend smaller instruments than formerly, with more compact switchboard and control board designs. With these new lines we will hasten the time when the switchboards for the largest power plants will be miniatures of the types heretofore used. These new a.c. instruments are on the same basis of "ideal" design and "universal" application as the recently announced d.c. instruments which they match in appearance thus forming a complete and harmonious line of instruments of both a.c. and d.c. types.

Following are some of the principal articles and market reviews appearing in Iron Trade Review Dec. 6 to Dec. 27, inclusive:

DEC. 6

Pig iron production in November fell below 100,000 tons daily for the first time in a year, the output of 96,373 tons comparing with 101,375 tons in October. Total production in November was 2,891,191 gross tons against 3,142,642 tons in October. Production has declined 22.8 per cent from the high point last May.

Iron Trade Review's composite of 14 leading iron and steel products this week stands at $43.02, compared with $42.80 last week and $42.63 two weeks ago.

Structural steel demand has improved and railroad buying is on a larger scale. The scrap market has advanced. Recent bookings of pig iron tonnages for the first quarter by some furnaces have been the largest in their history. Prices show more stability at higher level.

The layout and methods of handling of material at the new plant of a large iron and steel jobber in Philadelphia are described by E. C. Kreutzberg, of Iron Trade Review's New York staff. The making and testing of steel balls is the subject of an article by K. H. Lansing.

DEC. 13

Steel ingot production in November declined 434,162 tons, or 8.8 per cent from October. November was the seventh consecutive month to show a loss, and production was 24.1 per cent under the high mark in April. The output was at the annual rate of 37,126,000 tons, against a similar rate of 40,735,000 tons in October.

Final figures on Lake Superior iron ore shipments for the year 1913 show a total of 59,036,704 for the vessel route. A total of 2,000,000 all-rail ore is estimated at this time. The year was very favorable in the ore trade.

Iron Trade Review's composite of 14 iron and steel products this week is $43.05, as compared with $43.02 last week. More forward buying of steel is the feature of the market. The Ford Motor Company has placed about 30,000 tons of steel products with mills and is negotiating for 30,000 tons of sheets. Some comment has been caused by the action of a Chicago producer of cold-rolled steel in adopting a Chicago base of 3.00c instead of quoting on a Pittsburgh basis.

The British proposal for a protective tariff has been made a dead issue for some time by the defeat of the Conservative party, a London staff cablegram states. British business is undisturbed. English consumers purchase 100,000 tons of Belgian billets.

This issue contains a comprehensive write-up of the annual meeting of the American Society of Mechanical Engineers, New York.

DEC. 20

More contracting for steel products for the first quarter is the outstanding feature of the market this week. Automotive companies are taking the lead in the movement. The Ford Motor Co. has distributed among several mills the 30,000 tons of sheets for which it recently inquired. A northern Ohio manufacturer of automotive parts has closed with several mills for 15,000 to 20,000 tons of spring steel for the first half.

The United States Steel Corporation reaffirms for first quarter the price of $42.50, Pittsburgh on semi-finished steel. Rail orders are heavy. Among recent orders is one for 102,500 tons for the Santa Fe system for 1924 delivery.

Iron Trade Review's composite of 14 iron and steel products this week is $43 against $43.05 a week ago. Certain grades of pig iron are failing to hold up to recently announced levels; particularly true of basic iron, on which $20, valley has been done.

The beginning of heavy buying in Great Britain is reported by Iron Trade Review's European manager. Pig iron purchases of the week aggregate 100,000 tons, 70 per cent of which comes from Belgium.

At an export trade conference held in Cleveland under the auspices of the Cleveland chamber of commerce, James A. Farrell, president, United States Steel Corporation, emphasizes the need of American exporters cultivating "secondary markets" while Europe "remains in a chaos of political conflict."

Selective immigration is favored at the national immigration conference held in New York under the auspices of the National Industrial Conference board.

DEC. 27

Buying is on the upgrade in the iron and steel markets as the year closes. Consumption is large and the outlook is highly favorable for a good volume of business in the first half of 1924. Steel production is 70 to 71 per cent of capacity, for the whole country, compared with 80 per cent a year ago. The steel corporation's plants are operating at 84½ per cent. The steel market is fairly active as users continue to cover for future requirements.

The General Motors Corporation has closed for its first quarter tonnage with a number of mills; its normal requirements for a quarter are around 100,000 tons. The Willys-Overland Company has closed for 25,000 to 30,000 tons for first quarter. An automotive contract placed in the Chicago territory calls for 12,000 tons. The pig iron market is quiet, makers entering the new year with good order books. Iron Trade Review's composite of 14 iron and steel products this week is $43.02, a slight advance in the week. This figure compared with $40.65 a year ago.

British railroads buy more equipment. The London & Northeastern announces an expenditure of £5,000,000. British sheetmakers organize an export combination. Ruhr operations are expanding under the recent Franco-German operating agreement. A dozen blast furnace stacks are active and more are to be blown in. German offerings are increasing.

An article by the Japanese correspondent of Iron Trade Review describes Japanese reconstruction plans.

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Production of Iron in the Blast Furnace*

A Most Systematic Investigation of Furnace Phenomena

By P. H. ROYSTER†, T. L. JOSEPH‡ and S. P. KINNEY§

IN the blast-furnace process solid lumps or particles of iron ore at ordinary temperatures are charged into the top of the furnace and pig iron is discharged molten at the bottom. Inside the furnace therefore two changes of primary importance obviously take place. First, the iron oxide of the ore is converted to metal, and, second, the cold solids—ore, lime stone, and coke—charged, are heated to a high temperature.° One of these reactions is chemical; the other is physical. Both of them, however, are accomplished through the agency of the gas which is forced by the blowing engines upward through the voids in the charge. This gas, which the writers some years ago had occasion to term "bosh gas," is formed in the immediate neighborhood of the blast entrance, and has essentially the same composition in every furnace, regardless of the materials used, the design of the furnace, or the manner of its operation.¶ With dry blast and no volatile matter in the coke its composition would be 34.34 per cent CO, 65.66 per cent N_2. Moisture in the blast and traces of volatile matter in the fuel may introduce a per cent or so of hydrogen.

The heat generated when bosh gas is formed is sufficient to raise it to a high temperature, 1800 deg. C. or more. This temperature is sufficient to melt all forms of iron, coke-ash, ore-gangue, or fire-brick. As the gas passes upward through the furnace it meets the descending solids and an exchange of heat takes place, cooling the gas and heating the solids. The conditions under which bosh gas transfers heat, and carries out the chemical process of converting iron oxide into a metal is not known with any great accuracy. Since, however, the economy of the smelting process is governed by the extent to which bosh gas performs these two functions, it is possible that better knowledge of the phenomena will be of value to the industry.

The U. S. Bureau of Mines has been studying the blast-furnace process for a number of years and has published a number of papers therefrom.° During this study an experimental furnace has been developed by the Bureau in co-operation with the University of Minnesota, and data have been collected which seem worth recording. The writers propose to discuss here the bearing of these results on the problem of iron-ore reduction. The exchange of heat, of course, is equally important and it may be convenient to deal with that problem in physics elsewhere. Both functions of the gas are important, but since one is a chemical problem, and the other physical, it is perhaps wiser to consider them separately. A failure, however, on the part of the bosh gas to act satisfactorily, either as a reducing agent, or as a source of heat, will seriously interfere with, if not completely, interrupt the process.

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‡Assistant Metallurgist, Minneapolis Experiment Station.

§Assistant Metallurgical Chemist, Minneapolis Experiment Station.

¶"Combustion of Coke in the Blast Furnace Hearth," by G. St. J. Perrott and S. P. Kinney; paper read before February, 1923, meeting of A. I. M. & M. E. Abstrated in Mining and Metallurgy, vol. iv, 1923, p. 145. Those writers found no appreciable difference in composition of the gas near the tuyeres at 11 American blast furnaces. Their paper contains references to similar investigations.

°(a) A method for measuring the viscosity of blast-furnace slag at high temperatures, by A. L. Feild. Tech. Paper 157, 1916, 29 pp.

(b) Slag viscosity tables for blast-furnace works, by A. L. Feild and P. H. Royster. Tech. Paper 187, 1917, 38 pp.

(c) Temperature-viscosity relations in the ternary system CaO—Al_2O_3—SiO_2, by A. L. Feild and P. H. Royster. Tech. Paper, 189, 1918, 36 pp.

(d) War Minerals Series No. 5, 6, and 7, 1918.

(e) Uses, preparation, mining costs, manufacture of ferro-alloys, by C. M. Weld and others. Bull. 173, 1920, 209 pp.

(f) Pyrometry in blast-furnace practice, by P. H. Royster and T. L. Joseph. A. I. M. & M. E. volume on Pyrometry, 1920, pp. 544-558. Discussion pp. 558-567.

(g) Combustion of coke in blast-furnace hearth, by G. St. J. Perrott and S. P. Kinney. Paper before Feb., 1923, meeting cr. A. I. M. & M. E. Abstd. in Min. & Met. vol. 4, 1923, p. 145.

(h) Combustibility of blast—furnace coke, by Ralph Sherman and S. P. Kinney: Iron Age, vol. III, 1923, pp 1839-1844.

(i) Progress in blast-furnace research, by P. H. Royster, T. L. Joseph, and S. P. Kinney. Reports of Investigation Serial No. 2524, Bureau of Mines,, Sept. 1923, 6 pp.

Reducing Power of Bosh Gas.

If it were possible to remove all of the oxygen in iron ore by carbon monoxide, that is, if the equation

$$Fe_2O_3 + 3CO = 2Fe + 3CO_2 \qquad (1)$$

could be carried to completion, it would be chemically permissible to burden a furnace with a charge carrying 10,000 lb. of coke, 46,400 lb. of average Lake iron ore, and 13,300 lb. of limestone.

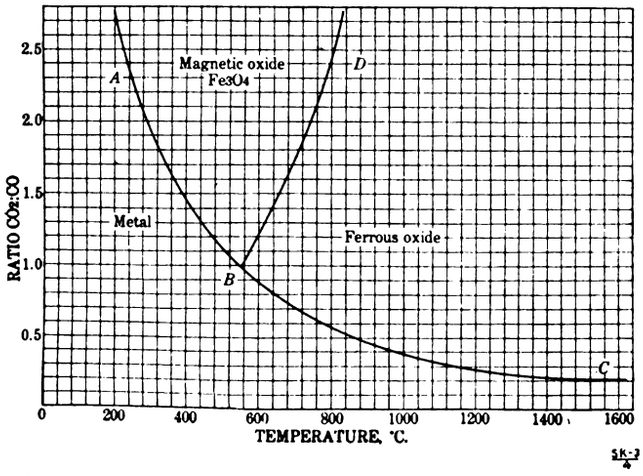

FIG. 1—*The CO_2/CO ratio, which is in equilibrium with metallic iron and its two lower oxides at various temperature.*

The furnace would make, at 18,400 cubic feet of wind per minute, 500 tons of pig iron a day with 860 lb. of coke per ton, provided no secondary reactions between carbon, its oxides and iron oxide took place. With this practice the furnace gas would analyze as follows:

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Constituent	Per Cent
CO_2	37.5
CO	0.0
H_2	2.0
N_2	60.5

No such burden or gas analysis has been approached, expected, or even hoped for in practice. Nevertheless, if carbon monoxide is to be called a "reducing agent," its reducing power cannot very well be said to be used up as long as the discharged gas carries CO with it. It happens that about 22 per cent is as low as is usually found. Apparently then no more than one-third of the reducing power of CO is used, because the gas carries only 34 per cent CO when it leaves the combustion zone.

Bell* gave the problem serious attention as early as 1860. As the result of many laboratory and plant experiments he came to two conclusions; "First, that something like the last third of the original oxygen in iron oxide could not be removed by CO; and second, that whenever the ratio of CO_2 to CO exceeded a certain value(which for the ore he was using he placed at 0.4 to 0.5), the gas was oxidizing, instead of reducing. These conclusions or theories are independent. The first theory states that there is some chemical peculiarity of iron oxide which prevents CO from separating the last portion† of the oxygen. The second takes no account of the iron oxide at all, but says that after the bosh gas has picked up enough oxygen to lower its CO content to some 20 to 24 per cent, the gas is "spent" and is no longer reducing at all. The writers have felt impelled to style these two conclusions "theories," because from the evidence at hand today it does not seem that they are sound either in theory or in practice.

Two Theories of Limited Reduction.

The theory that the last fraction of oxygen in iron ore cannot be removed by CO, immediately found wide popular favor. It was incorporated in textbooks‡ and is accepted as a fact by a large number of furnace men. There is, nevertheless, little scientific basis for the theory. Experimental work in point is fragmentary. In defense of the theory it might be possible to imagine such a compound as Fe_2O (containing 12.5 per cent O_2) which can be supposed to be unaffected by CO. This would be rather poor chemistry but it would help the theory. Another way would be to imagine that FeO forms a solid solution with Fe (it is known not to), and to build from this a hypothetical chemical system with properly assumed pressures and free energies.

There is more information available on the second theory. Eastman§ has recently assembled all the experimental work on the equilibrium conditions for the system Fe-C-O, which included the results of 14 investigators. The CO_2/CO ratio, which is in equilibrium with metallic iron and its two lower oxides at various temperatures, is shown in Figure 1. This curve is taken from Eastman's paper. It is conceivable that

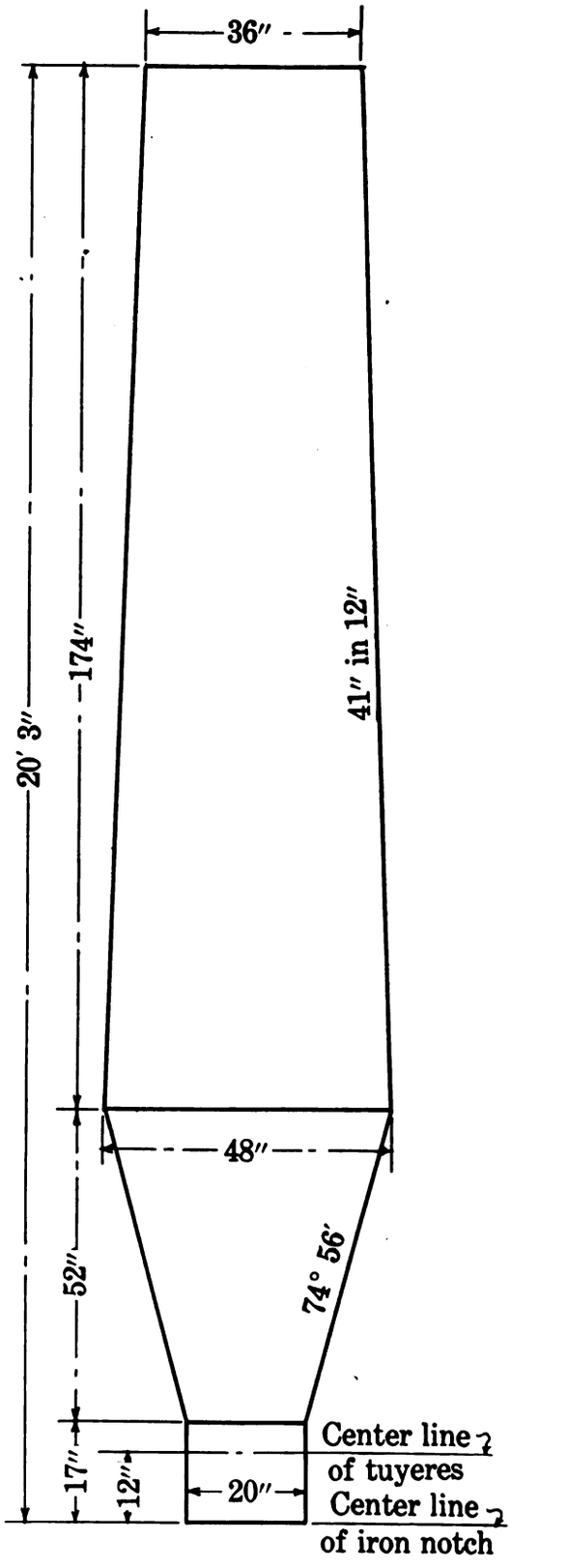

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FIG. 2—*Outline drawing showing the exact dimensions of the experimental blast furnace now in operation...*

*Bell, I. Lowthian, Chemical Phenomena of Iron Smelting, 1872.

†This last portion has often been called the "last traces," but, since it amount from 20 to 30 per cent, "traces" is misleading.

‡Campbell, H. H., Manufacture of iron and steel, 1907, pp. 60-61, (McGraw-Hill, New York). Forsythe, Robert, The Blast Furnace, 1913, p. 191 (David Williams Co., Cleveland). Johnson, J. E., Principles, operation, and products of the blast furnace. 1918, pp. 143-147 (McGraw-Hill, New York).

§Eastman, E. D., Equilibria in the system Fe:C:O: Jour. Amer. Chem. Soc., vol. 44, 1922, pp. 975-998.

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TABLE I — ANALYSIS OF MATERIALS AS CHARGED

COKE ASH		COKE ULTIMATE		COKE PROXIMATE		LIMESTONE		ORE	
	%		%		%		%		%
Fe	18.4	S	0.83	S	0.83	CaO	51.62	Fe	52.13
SiO_2	40.4	H_2	0.54	V.M.	2.33	MgO	0.61	SiO_2	11.13
Al_2O_3	22.7	C	80.02	Ash	12.17	SiO_2	1.05	Al_2O_3	1.22
CaO+MgO	5.6	N	0.84	F.C.	80.65	Al_2O_3	0.35	CaO+MgO	0.39
		O_2	0.75	Moist.	4.85	Fe_2O_3	1.14	I.L.	3.35
						Moist.	3.20	Moist.	8.54

TABLE II — OPERATING CONDITIONS

Blast Temperature—750 deg. F.

Blast Pressure—1.32 lb. per sq. in. gage.

Top Temperature—660 deg. F.

Wind—336 cu. ft. per min, actual air. 2 97 cu. ft. per min. air at 32 deg. F, 29.9 in. sea level barometer, dry. 3.52 grains of moisture per cubic foot of dry air.

Tuyeres—One 3-inch; one 2½ inch; 180 deg. apart.

Steel Jacketed Bosh—Water-sprayed; 12.6 gallons of coolingw ater per minute, inlet temp, 61.7 deg. F., outlet temperature 77.2 deg. F.; cooling-water loss 1,630 Btu. per minute.

Coke—Per day, 8,050 lb. Rouds—Per day, 67.0.

many will take exception to this diagram. The curve ABC indicates that no matter what the CO_2/CO ratio, a sufficient increase in temperature will convert metallic iron into an oxide. It is more usual to think that an increase in temperature will reduce the oxide. Although this work is well known, little attention has been paid to it by furnace men. In the blast-furnace it is not known at what temperature reduction by CO takes place. Imagine it to take place at a high temperature, and the diagram agrees with the theorem that CO_2/CO cannot exceed a given value. Figures, recently quoted by Sperr and Jacobsen* show that CO_2/CO in the blast-furnace gas may run above 0.6, although 0.7 does not seem to have been reached. In Table III of their paper the amount of the original oxygen in the iron oxide removed by CO is 71.4 per cent maximum and 42.4 per cent minimum.

Bureau of Mines' Furnace.

Data from the experimental furnace operated by the Bureau at Minneapolis now tend to show that neither of these two theories can mean anything except that, as furnaces are usually built and operated, some 20 per cent of the oxygen in the ore will be left for removal by other means than CO, and that the ratio of CO_2/CO will not exceed say 0.7 per cent. If the last third of the oxygen is removed by the expensive "direct reduction" method, the fault lies in the blast furnace process, or in any natural difficulties presented by the physical or chemical nature of the ore. And if a ratio of CO_2/CO cannot be attained in practice higher than 0.7, the fault still lies with the design and operation of the furnace and not with any failure of the gas as a reducing agent. The question is one of some commercial importance and for this reason it is perhaps worth while to describe the Bureau's furnace and its operation somewhat in detail.

Fig. 2 is a drawing of the furnace lines.

The furnace was burdened with the following charge: 120 lb. of coke, 145 lb. of ore, and 50 lb. of limestone.

The fuel was of the size known as "nut coke," weighed 29.3 pounds and averaged 1,360 lumps per cubic foot. It had been passed through a 1⅜-inch opening and caught on a ¾-ich screen, but the largest diameter of the larger pieces was about 2 inches and some of the lumps were as small as ⅜ of an inch. The stone weighed 89.5 pounds and averaged 37,000 lumps per cubic foot. The ore—Mesabi non-bessemer—was crushed and screened to pass a ¾-inch grizzly, and caught on an ⅛-inch screen. It weighed 103.8 pounds, and averaged about 15,000 to 25,000 pieces per cubic foot. Neither the ore nor the lime stone could be called "sized" in any strict sense. The analysis of the materials as charged is given in Table I, and the usual operating data in Table 2.

The stockline was measured and recorded 12 times an hour at two points and by measurements before and after each round. The average round was found to measure 9.05 inches thick the stockline being kept 34.5 inches below the lip ring. The stockline area at this elevation is 8.03 square feet, indicating that each round occupied 6.05 cubic feet. The constituents of the round and their measured volumes calculate just this for the volume of a round, indicating that with the materials used there was no measurable amount of stone or of ore spilling into the crevices between the lumps of coke. The calculated yield of metal from each round was 82.6 pounds of pig iron and by analysis the metal was found to average C, 3.5 per cent; Si, 1.25 per cent, and S, 0.04 to 0.10 per cent.

(To be continued)

To know the speed of engines, shafting and individual machines is essential, in order to maintain the maximum plant operating conditions. Not only, to have occasional readings, but a continuous record showing comparisons and fluctuations from hour to hour. For these reasons Tachometers have been developed and are now being extensively used in the industries.

The Bristol Company's Bulletin 317 recently issued illustrates the various types of instruments used for indicating and recording this service.

A wide choice of equipment is available; both pneumatic and electrical applications are described, and much necessary information concerning installing and operation.

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Motorizing Structural Mill at Homestead

An Interesting Study Derived from Comparisons Between Antiquated and Modern Equipment

By S. S. WALES†

ALTHOUGH electric motor-driven rolling mills are now becoming quite common and attract little attention, an account of the "motorization" of the 33-inch structural mill at the Homestead Steel Works will be of interest on account of the unique feature that the installation of the motor was the only change made in the equipment.

It has been almost universally the case that the engineering department of a plant has in mind a number of changes, more or less drastic, to be made in the mill itself to improve its performance, which changes are made at the same time the motor is installed so that it is necessary to adjust the resulting benefits among several applicants each justly claiming a certain credit. With the 33-inch structural mill no change in the roll train, shoes, housings, bearings, or methods of lining up and down was made, nor were the roll sections changed in any way until after the motor had been installed and run.

MR. S. S. WALES

Mill.

This mill was installed in 1892 and is of the three-high, continuous running type, similar to that shown in Fig. 1, rolling up to 12-inch beams and 15-inch channels with such other standard and special structural shapes as fall within its capacity.

It consists of one roughing and one finishing stand normally carrying six passes in the roughing and four in the finishing rolls. The rolls are of 33-inch theoretical centers, have 20-inch diameter necks, and are 74 inches between bearings. They are made of standard material such as gray cast iron or steel.

The mill was designed to take reheated blooms or cogged shapes up to 9½ inches by 11 inches. The bloom is received from the heating furnace and is handled on each side of the mill by electrically-driven travelling pass tables, which move parallel to the mill, receiving the out-coming piece and returning it to the proper pass until it finally is delivered to the cooling beds. The cooling beds were of ample capacity for the mill when run by the steam engine.

This very valuable article shows the results obtained by just substituting an electric motor for a steam engine on a 33-inch structural steel mill at the Homestead Steel Works. A study of the summary of these results is very instructive.

Engine.

The engine was built by the Southwork Foundry & Machine Company and was of the well-known Porter-Allen type, horizontal simple engine, with 54-inch cylinder and 66-inch stroke, and with a 24-foot, 180,000-pound flywheel. It was designed to work under a steam pressure of 125 pounds and atmospheric exhaust with a speed of 65 rpm.

Motor.

The motor selected to replace this engine was a 4000-h.p., 25-cycle, 3-phase, 6600-volt machine with a synchronous speed of 83.3, illustrated in Fig. 2. The efficiency is calculated to be 94.5 per cent with a power- factor of 81 per cent and a speed of 82 rpm. at full load. It will deliver 4000 h.p. continuously with a rise of 35 deg. C. above the surrounding air, and 6000 h.p. with a 50 deg. rise, and is capable of exerting a maximum running torque of approximately 700,000 lb.ft. corresponding to 10,500 h.p. It is provided with a cast steel flywheel 19 feet in diameter, with 16-inch face, weighing 170,000 pounds and the combined stored energy of the rotor and flywheel is approximately 18,400-h.p.-sec. An extra section of resistance sufficient to give 5 per cent additional slip is installed which is cut into the rotor circuit by means of a notch-back relay and contactor, if the load on the motor exceeds approximately 150 per cent normal torque. The motor can be started, stopped or reversed by means of push buttons mounted near the mill or by a master switch inside the motor room.

*General Electric Review.

†Chief Electrical Engineer, Carnegie Steel Company, Pittsburgh, Pa.

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While it would have been desirable to direct connect the motor and raise the speed of the mill to 83.3 it was thought best not to experiment along this line at the start so a reduction gear with a ratio of 20 to 16 was introduced between the motor and the mill pinions.

The motor was started on its regular working program during June, 1921, and has continued without interruption to the present time, the only repairs being the renewal of contact tips on certain parts of the control system due to the severe strain put on them in "wedging up" the rolls in the process of "lining" where it is necessary to successively start and stop the mill for a movement of only a few inches on the surface of the rolls.

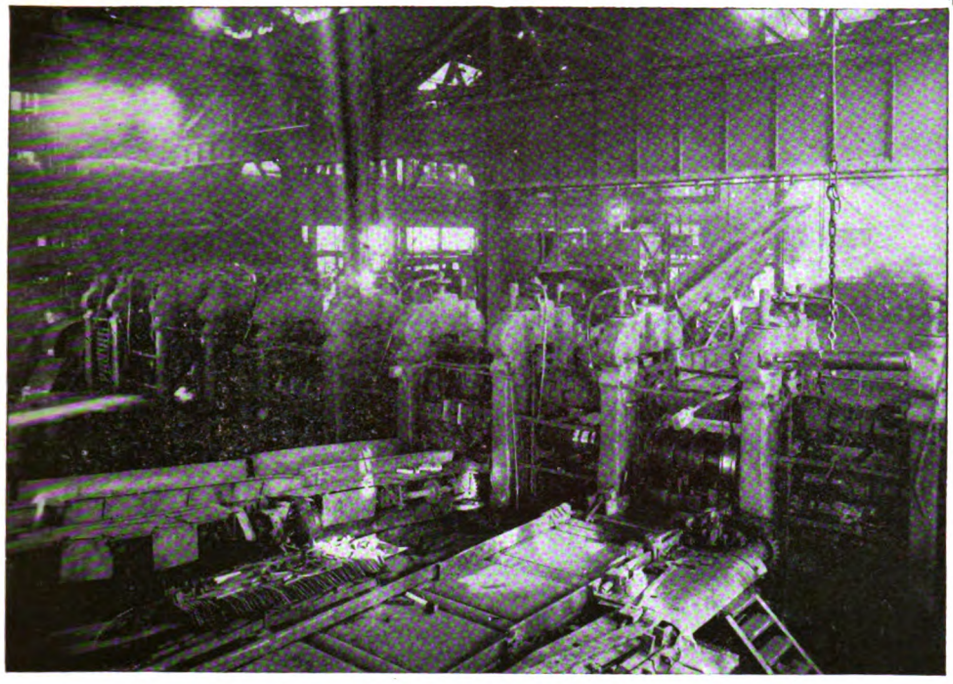

FIG. 1—*Structural steel mill similar to that described in this article.*

Results.

It was noticed almost immediately that, whereas the engine used to slow down and drag on the long finishing passes, the motor held up to speed and that the finished piece was delivered to the cooling beds much hotter than before. This led to cutting the ingot into two blooms instead of into three blooms per ingot as was the former practice, further increase in weight being precluded by lack of room in the mill, as designed, to care for the extra length of the finished piece.

The trouble which had always been experienced in variation in weight of section sometimes amounting to several per cent was entirely eliminated, even with the 50 per cent increase in length due to using two cuts instead of three cuts to the ingot. The only difficulty encountered due to the change was that the cooling beds proved to be inadequate to care for the increased tonnage which could now be handled, so placing the limit on the output of the mill.

It was feared that the great reserve power of the motor would cause serious trouble in case of a piece being "cobbled," and that an increase in roll breakage would result, but this has not proved to be the case, the result being fewer cobbles and a considerable decrease in roll breakage. This is probably due to the uniformity of speed the motor maintains and the ample power provided, which eliminates slow rolling and serious loss of temperature during the process.

One very noticeable advantage of the motor over any other method of driving a rolling mill is the intimate knowledge it provides the operators and roll designers regarding the power required for each pass, by means of continuous chart-drawing instruments. The flow of plastic steel under pressure is governed by so many things that the power may vary over wide limits, for reductions of area which are practically equal, especially when structural shapes are being rolled. It is possible to distribute this work over the passes to the best advantage for the mill and the finished product if the work done in each pass is known.

Charts.

Fig. 4 shows a reproduction of a chart taken at 12 inches per minute with a swing of the pen equal to one half inch per 1000 kw. In this curve and those following, the wavy shape at the top and bottom is probably due to the sensitiveness of the instrument and the vibration of the ground caused by the running of the mill. The high saw-tooth form of the curve for changes from friction load to full load and back appears to be due to lack of dead beatness in the instrument allowing the pen to over swing in both directions.

Figs. 3, 5, 6 and 7 are reproductions of a chart

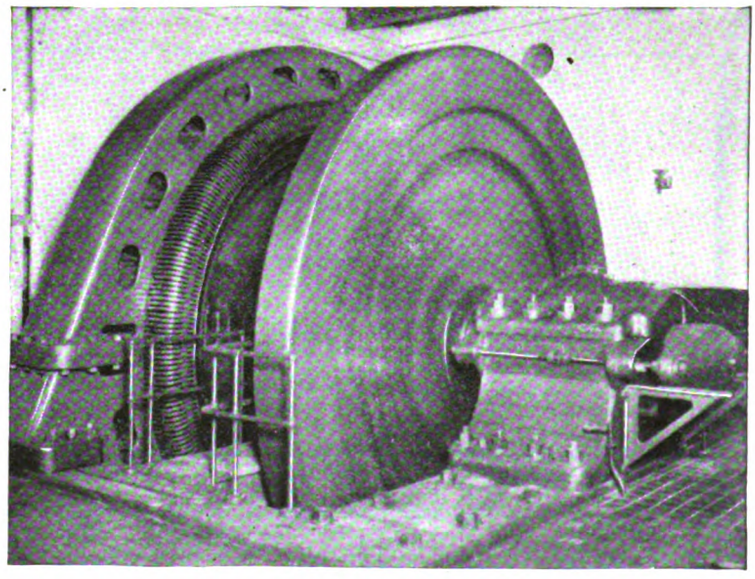

FIG. 2—*4000-h.p., 25-cycle, 3-phase, 6600-volt induction motor for driving the 33-inch mill.*

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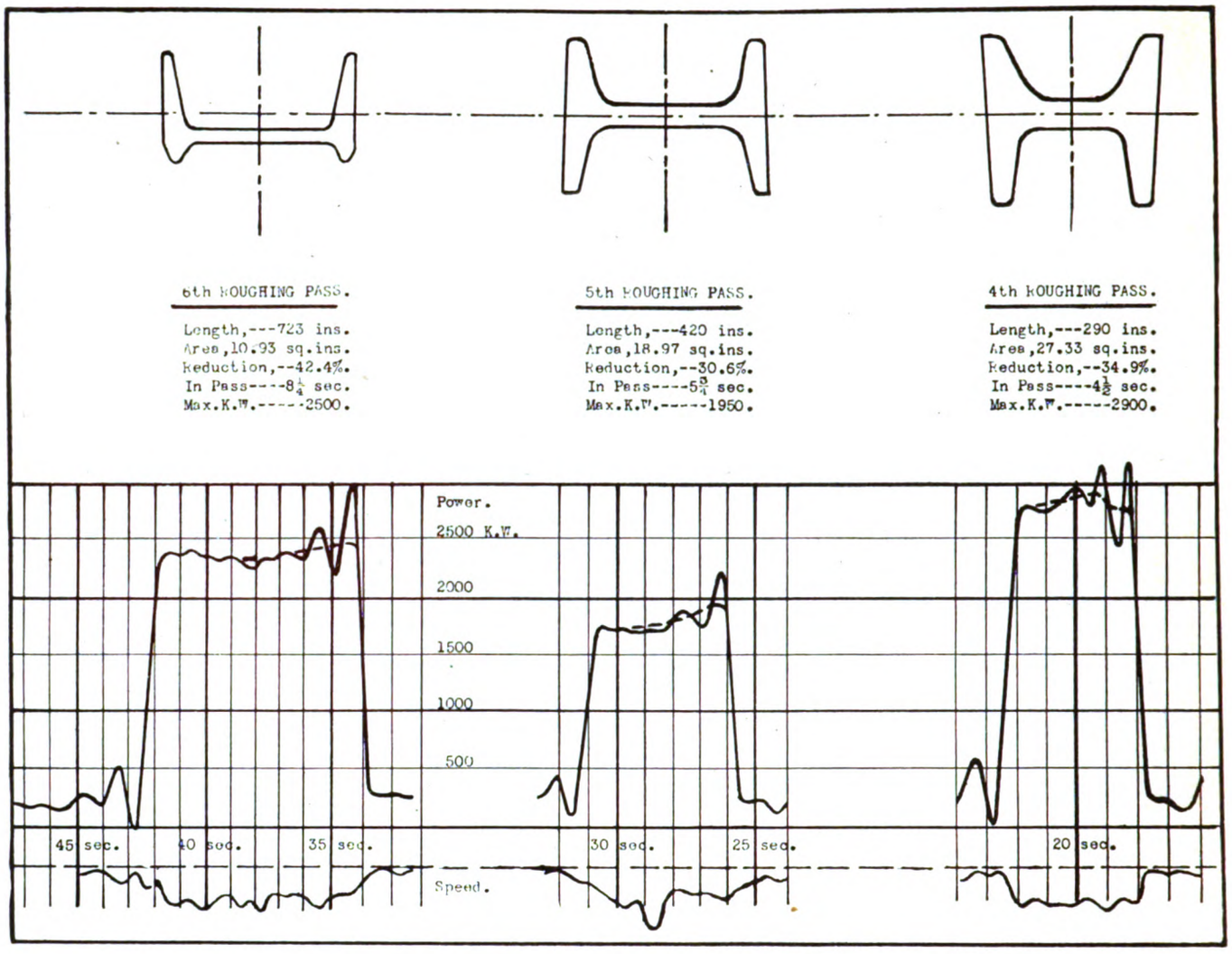

FIG. 5—*Showing the final roughing passes.*

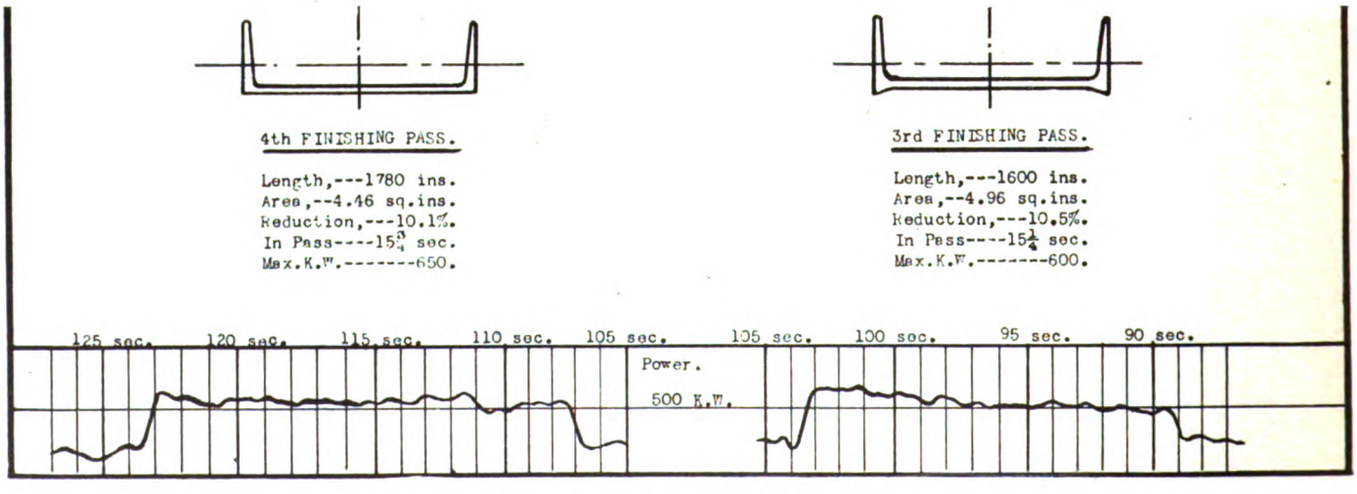

FIG. 6-B — *Showing the final finishing passes.*

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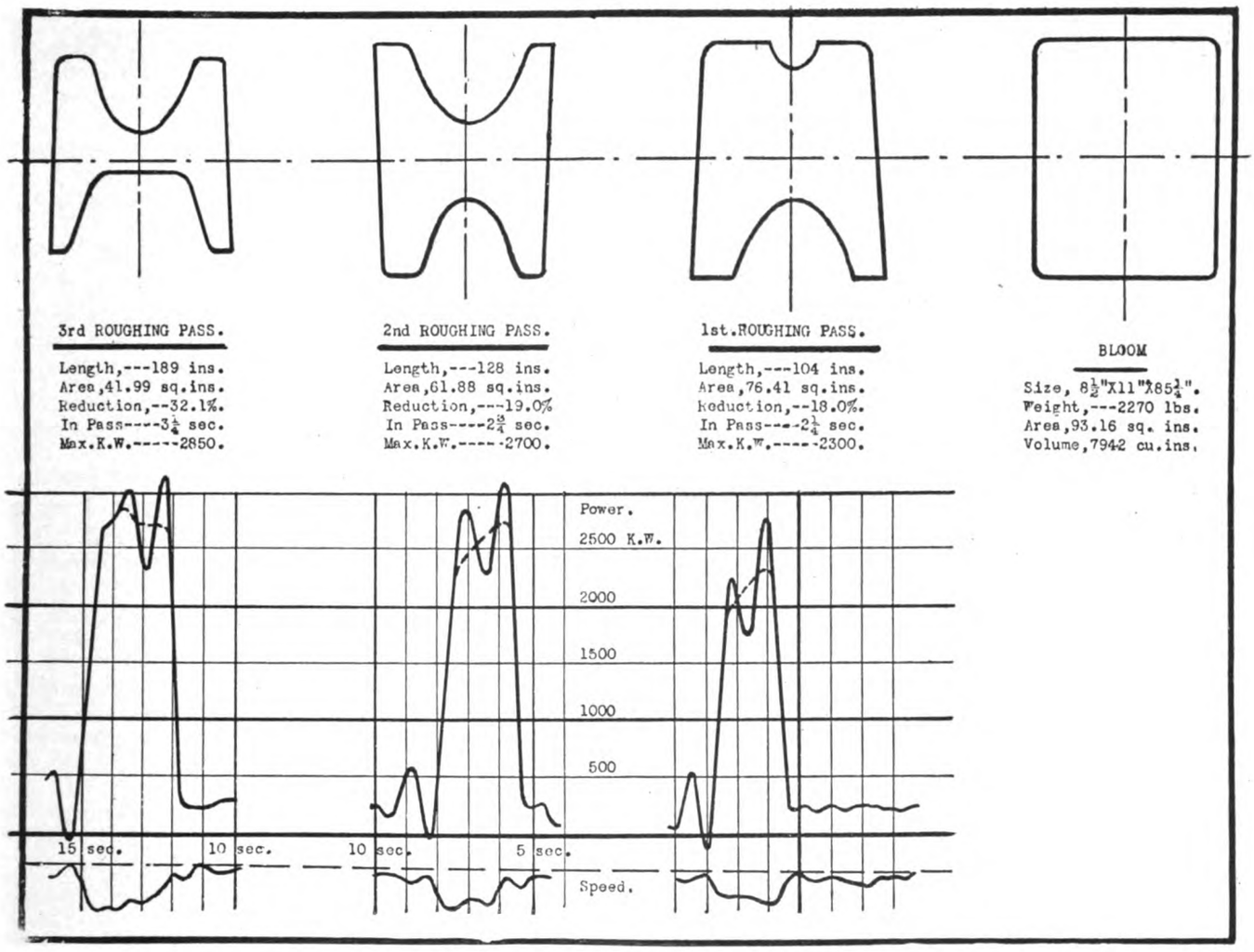

FIG. 3—*Showing the bloom and the first roughing passes.*

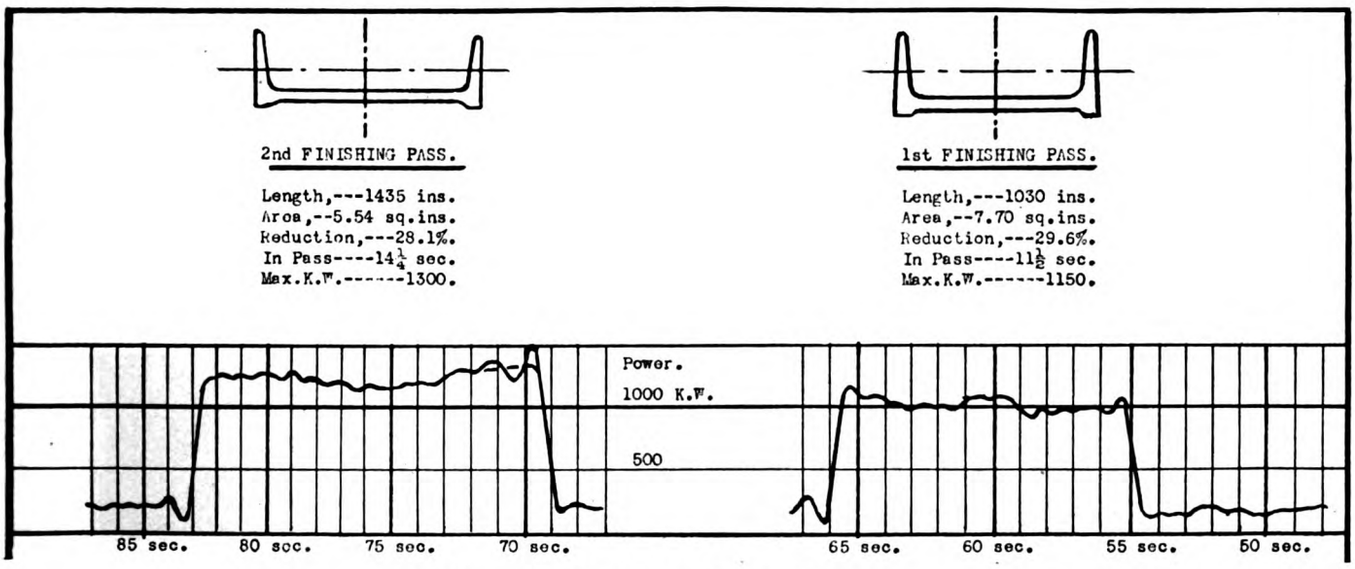

FIG. 6-A—*Showing the first finishing passes.*

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taken at 18 inches per minute with a swing of 1 inch per 1000 kw. The speed curves at the bottom are of interest only as showing the drop in speed under load, which allows the fly-wheel to function. The speed curve is omitted for the finishing passes as there is

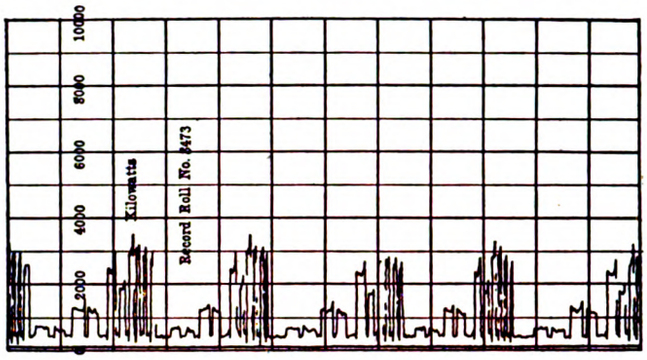

FIG. 4—*Curve drawing instrument chart showing the fluctuating character of the load.*

hardly any noticeable decrease of speed under the power demands at this point. The curve has been spread to allow better opportunity for study and a picture of the section resulting and the data for the pass are shown above the curve. In these chart curves

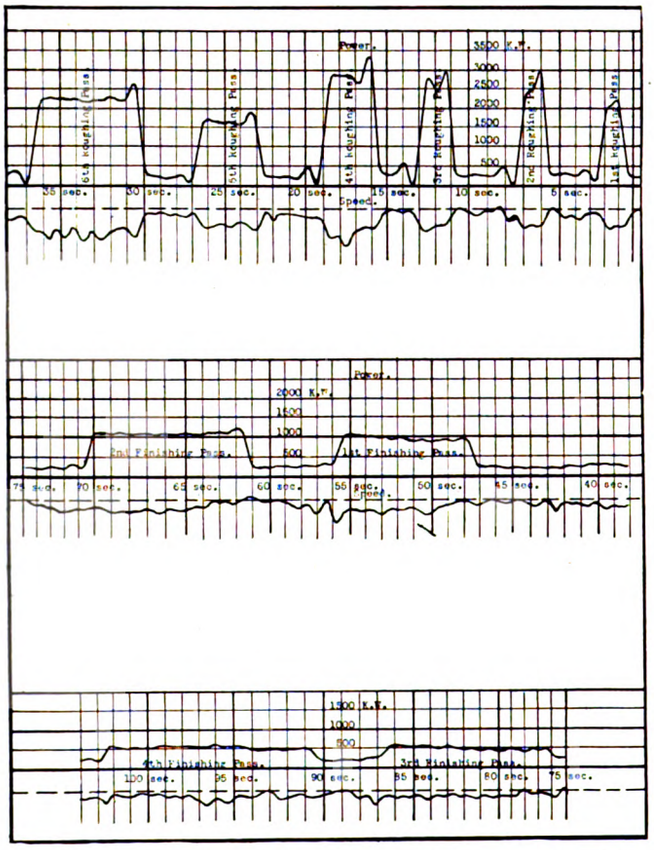

FIG. 7—*Reproduction of chart taken at* 18*-in. per min, with a swing of* 1 *in. per* 1,000 *kw.*

the time is shown in five second blocks evenly divided into single seconds which is near enough for all practical purposes. These chart curves form a basis for some very interesting study and need no discussion in this article.

Summary.

As no change was made other than the installation of the motor in place of the steam engine, the electrification of this mill may be credited with the following:

1. More convenient operation due to push button control for starting, stopping and reversing.
2. Cheaper operation due to less attendance, and practically no repairs.
3. Greater tonnage and fewer pieces to handle due to the reserve power inherent in the electric motor.
4. Fewer cobbles and reduced roll breakage.
5. More uniform sections with less difference in weight of finished piece, due to quicker finishing.
6. Assistance to roll designer derived from recording chart.

To Make Power Survey of Pennsylvania

As a commission from Governor Gifford Pinchot, a power survey of the State of Pennsylvania has just been instituted by the Commercial Engineering Department of Carnegie Institute of Technology. Dr. W. F. Rittman, head of the department, and Prof. Sumner B. Ely are making the survey under the directorship of Morris L. Cooke of Philadelphia.

As the purpose of the study is to determine the approximate consumption of horsepower necessary to operate Pennsylvania industries over a given period of future years, the survey is considered to be one of the most important in the state's history. In order to make such an estimate possible, the Carnegie Tech engineers have been asked to survey the total consumption of power used in the state industries in the past 20 years.

Because of the relative importance of the state survey, Dr. Rittman and Prof. Ely have been assured of the utmost co-operation by engineers and heads of industries throughout the commonwealth. The Carnegie Tech investigators, who have just completed a power survey of the Pittsburgh District upon their own initiative, will have a wealth of information derived from this study upon which to construct their state-wide research.

Governor Pinchot's faith in the possibilities of a power survey of the state was expressed in a statement issued last summer when he said: "In an advancing social order, power must be both cheap and plentiful. Therefore every possible economy must be practiced. This implies the conception of a state-wide (and ultimately a nation-wide) reservoir or pool of power into which we may pour energy from whatever source, and from which storage we may take out energy to meet widely diversified scattered needs.

"Giant power means cutting out waste. The burning of raw coal in power plants and on our railroads has come to be recognized as waste, involving, as it does, the loss of by-products such as ammonia, needed for fertilizer on the farm; tar for road-building, and other hydrocarbons useful as dyestuffs and otherwise in the industries. If these economies can be realized through building large scale by-product distillation and power plants at the mines, it will mean cheaper power because of the reduction in the cost of fuel, which today constitutes upward of three-quarters of the whole cost of steam developed electric current.

The Carnegie Tech engineers plan to complete their survey by the end of summer of 1924.

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Complete Modern Ore Bin System

Great Labor Reduction Effected by New Mechanical Handling Equipment

IN anticipation of the labor difficulties which many iron and steel producing plants are at present experiencing, the Adrian Furnace Company of Du Bois, Pa., decided during the summer of 1922 to install a modern and permanent storage bin and trestle system, together with scale cars, and transfer car, and other necessary auxiliary equipment.

The blast furnace at Du Bois was placed in operation on April 6th, 1923, and with the new mechanical handling equipment it has been possible to reduce the number of men employed in the stock house from 19 to 3 men per shift.

When the furnace was last blown out, in August, 1922, it was decided to begin the improvement program at once, and Arthur G. McKee & Company of Cleveland were selected as engineers and contractors and were awarded a lump sum contract for the entire work.

In selecting a location for ore storage, it was decided to utilize a site adjoining the property of the Rochester & Pittsburgh Coal & Iron Company, which company also controls the Adrian Furnace Company property. This procedure made it possible to bring into service a traveling bridge which was originally installed by the Rochester & Pittsburgh Coal & Iron Company for handling and storing coal. By providing a slight curve and extending the crane runway, the bridge now can traverse the ore storage and serve the transfer car operated in connection with the new trestle and bin system. It was also necessary to change the center line of the new concrete trestle to a point 3 ft. 6 in. distant from the center line of the old wooden trestle, which was practically completely dismantled.

As shown in the accompanying illustrations, the new bin and trestle structure, comprising a total of 33 bents, is 480 ft. in length and is of steel and reinforced concrete construction. The height of the trestle at the skip pit is 27 ft. to top of rail, and is provided with walkways on each side of the trestle tracks with steel handrailing 3 ft. 6 in. high.

Suspended from the reinforced concrete supporting structure are six ore and stone bins, each 15 ft. in length, center to center of bents. The bins are of the Baker suspension type and of steel plate construction, ⅜ in. thick, braced and reinforced with angles and beams. For direct discharge into scale car, the bins are equipped with a continuous row of segmental type gates, which are easily operated from the scale car platform. The scale car for carrying ore and stone from the bins to the skip pit is electrically operated and is of heavy steel construction. The car is of the

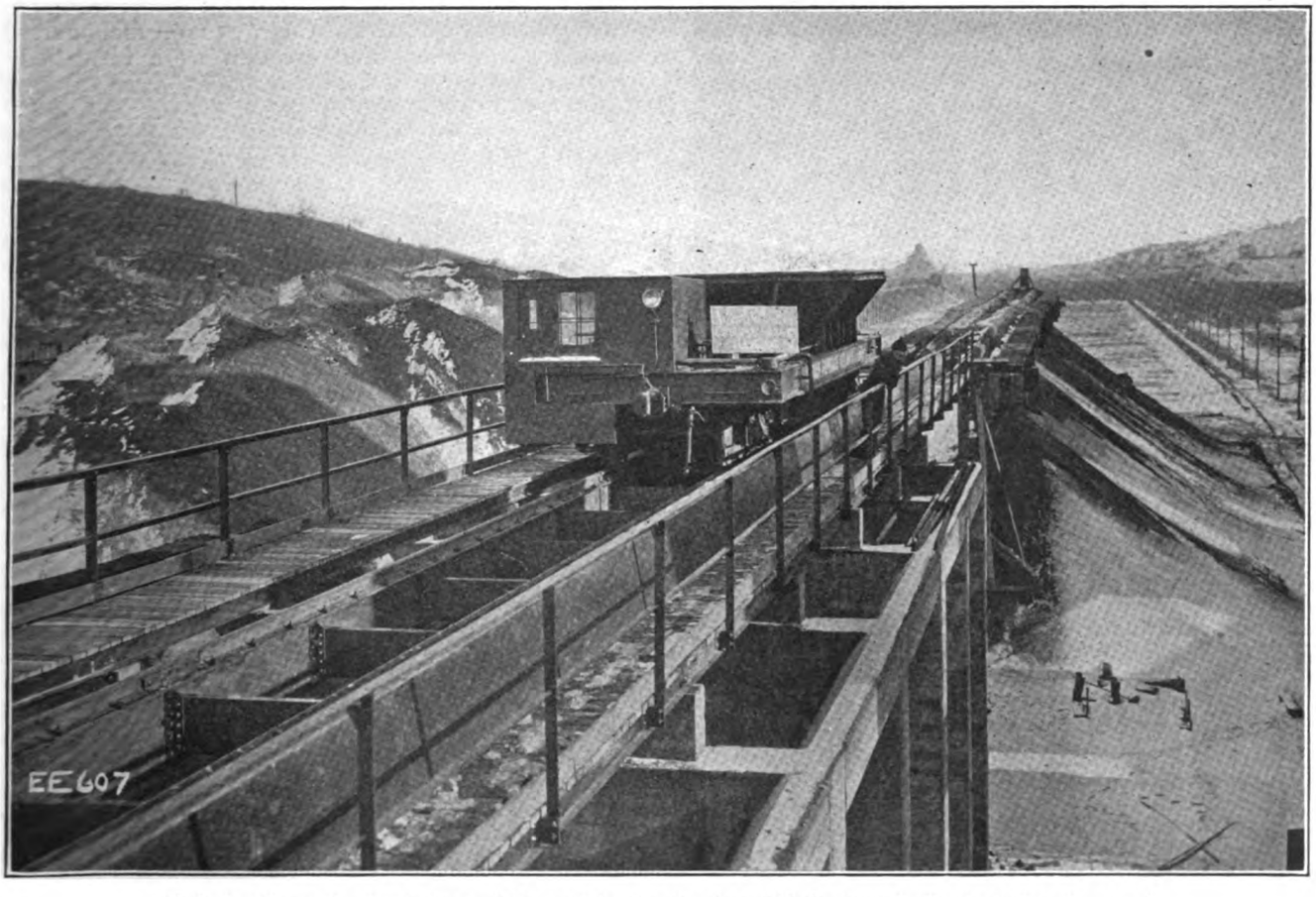

FIG. 1—*Shows the track level of bin and trestle structure* 480 *ft. long, built of steel and concrete.*

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center discharge type, with side platform, the control and scale equipment, car discharge and bin discharge mechanism being so arranged that they are all easily accessible to the scale car operator.

In order to accommodate the new arrangement it was necessary to deepen and enlarge the existing skip pit, and to extend the travel of the skip cars.

The coke bin is of the central discharge type, and is 45 ft. in length, center to center of bents, occupying three bays in the trestle structure. The bin sides and bottom are of ⅜-in. steel plate, braced with structural steel members, all suspended from the concrete bents, wearing plates being provided in the lower portion of the bin. The coke bin is designed for a capacity of 135 tons of coke, level full.

For screening the coke, two McKee patented cascade coke screens were provided, over which the coke is discharged from the storage bin direct into the skip cars. Beneath the coke screens are two chutes which deliver the breeze to the boot of a bucket elevator. The breeze is then elevated approximately 30 ft. and emptied on to a 14-in. belt conveyor, which carries the material approximately 52 ft. and discharges direct into railroad cars. The belt conveyor is of standard

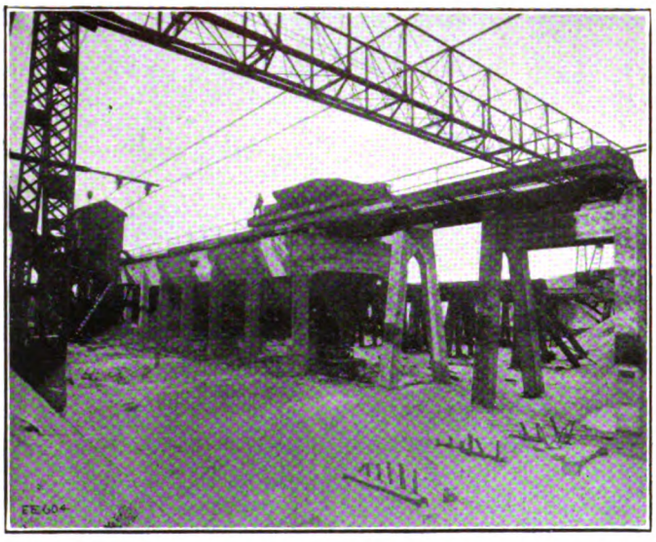

FIG. 2—*Another view of trestle showing bottom of bins from the yard level.*

construction, provided with 4-ply rubber covered belt, troughing idlers and return idlers. Power for driving is supplied by a 5-hp., 220-volt, d.c. motor.

Prior to the installation of the new handling equipment, operation of the skip hoist, furnace bells, etc., was accomplished from several remote points, and in order to overcome this disadvantage, a new operator's house was constructed. This house is located at the skip pit, on the furnace side of the coke bin, and with the new arrangement the operator has under his direct control the operation of the skip cars, coke bin gates, coke breeze disposal equipment, furnace bells and furnace gauging mechanism.

As previously mentioned, it was decided to convert the traveling coal bridge into an ore bridge and owing to the existing construction and clearance of the bridge and bucket, a special transfer car was required for distributing materials from the ore bridge to the respective storage bins. The maximum clearance obtainable was approximately 8 ft. above top of rail, necessitating the provision of a cab which would afford a full view of all operations and still meet the clearance requirements. For these reasons the car was designed with the cab located in a lowered position and supported by extending the car frame, as shown in the adjacent photograph.

The car has an overall length of 40 ft. 8 in., the hopper being 20 ft. 6 in. by 12 ft. 8 in. at the top, giving a capacity of 50 net tons. For discharging its contents the car hopper is equipped with two pairs of counterweighted discharge gates, so arranged as to dump the material symmetrically from the hopper. Opening and closing of the gates is effected by a mechanism of levers, cams and shafts, operated by means of air cylinders. An auxiliary hand operating mechanism was also provided, for use in case of failure of air supply.

The car is equipped with two four-wheel standard 50-ton M.C.B. arch bar trucks, Westinghouse air brake equipment, and is driven by two 51-hp., 250-volt, d.c. motors, one mounted on the axle of each truck. All auxiliaries, such as fenders, headlights, warning gongs, etc., are included in the car equipment.

In summarizing the foregoing, the new construction and equipment gives the Adrian Furnace Company a complete mechanical handling and storage system, which, by utilizing certain existing equipment, was provided at a minimum expenditure.

Reconstruction work was completed February 9, 1923. The interests of the Adrian Furnace Company, in connection with the improvement program, were handled by Mr. F. G. St. Clair, general manager. All designs, equipment and erection were furnished by Arthur G. McKee & Company.

Concrete Ties Used in Indian Railways

The Northwestern Railway of India has made exhaustive tests of a new type of concrete railway tie patented by a Delhi consulting engineer. Experiments have been made on 50 miles of main line track near Delhi and the results have been so satisfactory that a further 70 miles of track will be similarly equipped as soon as the necessary ties are manufactured, says a report to the Department of Commerce from Vice Consul Robert F. Kelley at Calcutta. The tie consists of two concrete blocks joined together by a tie bar, the rails being fastened by means of a screw or dog spike driven into wood plugs, specially treated and compressed, set in the bed of the concrete block. The other Indian railways are interested in concrete dies. The East Indian Railway has been using a large number of Green-Moore patent reinforced concrete ties for seven years and has now nearly completed a factory for manufacturing 500,000 railway ties per annum. The Green-Moore tie is the invention of the deputy chief engineer of the East Indian Railway and is similar in construction to the type in use on the Northwestern Railway. They have been favorably reported on by the senior government inspector of railways since 1915-1916, who states that they are still in perfect condition and show no signs of weakness. The Bengal Nagpur Railway has decided to adopt the Green-Moore tie and has acquired a license to manufacture 300,000.

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Metalloids in Basic Pig Iron in Basic Open-hearth Practice*

By C. L. KINNEY, JR.†

THE rapid increase in the amount of steel produced by the basic open-hearth process is an index of its ability to produce high-grade steel from raw materials of the most varied physical character and chemical analysis. This inherent adaptability of the process has resulted in a lack of care in the selection of raw materials, so that in far too many cases charges are used of a chemical and physical character not justified by local economic conditions.

A practice, or series of practices, should be used that will result in the greatest economy for the plant as a whole; therefore, the operations of blast furnace and open hearth must be considered together. In this paper, an effort has been made to show those variations in both openhearth practice and cost that follow changes in the analysis of the pig iron and, it may be said that, the theoretical costs shown are worthy of careful study and consideration.

Carbon, manganese, silicon, phosphorus, and sulphur constitute the principal metalloids in basic pig iron and play the leading role in the production of steel by the basic open-hearth process. The percentages of each of these metalloids, with the exception of carbon, is a variable that has its genesis in the economic relation of the blast-furnace plant to its ore and fuel supplies. As the amount of carbon in the iron is a saturation function of the temperature at which it is produced, the variation in the amount carried is, for any given locality and grade of iron, practically negligible and is so considered in the eight heats discussed in this paper.

An endeavor to emphasize the effect of varying percentages of silicon, manganese, and phosphorus in the basic pig iron, used in the basic open-hearth process, on the cost of steel; supplemented by calculations that exhibit the momentary losses sustained, when unnecessary quantities of silica or bases are used.

The melting and refining reactions in an open-hearth furnace, either acid or basic, are essentially oxidizing and vary greatly with the type and age of the furnace, as well as the character of the fuel employed. The outstanding characteristic of the basic process, and the one that explains its predominance over the acid, is its ability to form out of the lime charged and the phosphorus oxidized from the charge a stable calcium phosphate, which is held in solution by the basic slag. The necessity for such a process had its origin in the gradually diminishing quantities and increasing cost of iron ores having a phosphorus content sufficiently low to permit the production of iron, which contained an amount of this element small enough to make possible its conversion into merchantable steel by the acid process. So the problem is how, and to what degree, the changes in hot metal constitution affect burdening practice, for the open-hearth process is a metallurgical operation that takes various materials and produces steel to meet trade specifications; and the management must meet these chemical and physical specifications in the most economical manner possible.

In this paper, eight representative heats have been chosen and worked out on a chemical, or material, and thermal balance and then combined on a cost basis, in an effort to determine what grouping of materials will yield the lowest cost to them all as a unit.

The conversion of pig iron into steel requires the elimination, as far as possible, of the silicon, phosphorus, and sulphur and the reduction of carbon. The oxidizing action of the flame with high iron charges must be increased by the introduction of iron oxide in the form of ore, for these metalloids (except carbon) must be oxidized before they can be taken up and held by the slag. The principal slag-forming constituent is lime, and enough must be introduced with the charge to absorb and carry away the impurities. Any excess lime or ore charged is a distinct loss both in heat and material. An excessively thick slag offers an increased existence to heat transfer from gas to bath, and excess ore produces an overoxidized and soft melting heat, as well as heavy iron losses in the slag.

In our practice, a charge of 35 per cent metal (carrying 0.75 per cent silicon, 1.00 per cent manganese, 0.20 per cent phosphorus, 4.30 per cent carbon, and 0.04 per cent sulphur) together with 65 per cent scrap will, under average conditions, melt at approximately 0.50 per cent carbon, which is sufficient when making soft steel to give the active carbon boil so essential for the proper refinement of the charge. As is the case in all large steel-producing districts, the scarcity and price of heavy melting steel scrap make it more economical to substitute the high-percentage iron charge for the scrap; this substitution necessitates an enhancement of the oxidizing power of the furnace. This is accomplished by charging in the furnace, with the limestone and scrap, a predetermined amount of oxygen in the form of iron ore. The action of the oxygen, thus introduced, on the metalloids in the excess iron charged is a preferential one, at the temperatures prevailing in the furnace at the time the hot iron is poured on the limestone, scrap, and ore previously charged. The silicon, manganese, and phosphorus are first oxidized and, as the temperature rises, the carbon-oxygen reaction begins to predominate, and on further temperature rise it becomes the only one. It is at this period of the melt, because of the enormous volumes of carbon monoxide and carbon dioxide generated, that the gas-saturated slag occupies two or three times its normal volume; to prevent destructive erosion of the furnace structure, it is customary to run off from 30 to 40 per cent of this total slag. In spite of the fact that this run-off slag contains relatively high percentages of iron and manganese, in the form of silicates,

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†Superintendent of Open-Hearth, Illinois Steel Company, So. Chicago, Ill.

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which if held in the furnace could be more thoroughly reduced and their additional oxygen made available and the metal returned to the bath; the general practice is to waste this slag, and with cheap iron and ores, it is probably more economical to do so than to reduce the size of the charges and to use the additional fuel that the greater finishing slag volume would necessitate.

To illustrate the preceding principles, one scrap and seven ore heats have been calculated on a material and heat-balance basis. The analyses of the various pig irons and the names by which the heats will be hereinafter referred to are:

	Pig Iron Analysis				
Heat	Carbon Pct.	Silicon Pct.	Phosphorus Pct.	Manganese Pct.	Sulphur Pct.
Scrap	4.30	0.75	0.20	1.00	0.04
Standard iron	4.30	0.75	0.20	1.00	0.04
Standard iron, low-silica ore	4.30	0.75	0.20	1.00	0.04
High manganese iron	4.30	0.75	0.20	2.00	0.04
High manganese iron, low silica ore	4.30	0.75	0.20	2.00	0.04
Excess limestone	4.30	0.75	0.20	1.00	0.04
High silicon iron	4.30	1.75	0.20	1.00	0.04
High phosphorus iron	4.30	0.75	0.70	1.00	0.04

The scrap charge was 35,000 lb. hot metal and 65,000 lb. heavy scrap; all others were made up of 65,000 lb. hot metal, 35,000 lb. of scrap, and varying amounts of ore. "Low-silica ore" means that the ore carried 4.62 per cent. silica instead of 9.29 per cent as in the other cases.

It may be properly asked what advantage may be gained or reliance placed on results of heats calculated in this manner; all were calculated using the same factors and, in the cases that correspond to operating conditions in the Chicago district, the theoretical results obtained corresponded very satisfactorily with our actual operation. These typical heats, on a cost basis, showed the following results:

Scrap	$29.11
Standard iron	30.70
Standard iron, low-silica ore	30.27
High-manganese iron	30.27
High-manganese iron, low-silica ore	29.77
Excess limestone	31.57
High-silicon iron	32.21
High-phosphorus iron	31.12

While the scrap heat does not represent regular practice in the South Chicago district, it is included to show what economies might be realized by this simple melting process, when the relative cost of heavy melting scrap and iron permit. The heats with the low-silica ore have been included to show the savings possible from this source. The excess-limestone heat was included to show that this customary method of reducing sulphur is expensive.

As already mentioned, the open-hearth reactions are highly oxidizing, and the oxidizing capacity of the furnace when high percentages of iron are charged must be enhanced by the introduction of an amount of oxygen in the form of iron ore. The demand for ore will depend on the type and age of the furnace and the weight of metalloids charged. The method of determining the amount of ore needed will be explained later.

While the exact constitution of a basic open-hearth slag is not thoroughly understood and analyses vary over wide limits, a good slag will always possess certain outstanding characteristics. Such a slag may be considered to consist of a phosphate and a silicate portion, the former being held in solution by the silicate slag. Moreover the basic and acid constituents must be so proportioned as to permit the slag to hold the impurities, and also to be of the proper consistency at

TABLE 1.—*Comparative Costs of the Different Heats. Based on the Calculated Chemical and Thermal Balance Sheets and Market Prices of April, 1923*

Materials Used	Price per Gross Ton	Scrap			Standard Iron High-silica Ore			Standard Iron Low-silica Ore			High-manganese Iron High-silica Ore		
		Tons	Amount	Cost per Ton	Tons	Amount	Cost per Ton	Tons	Amount	Cost per Ton	Tons	Amount	Cost per Ton
Basic hot metal	$ 28.00	15.63	$ 437.64		29.02	$ 812.56		29.02	$ 812.56		29.02	$ 812.56	
Iron in ferromanganese	28.00	0.035	0.98		0.047	1.32		0.040	1.12		0.014	0.39	
Heavy melting steel scrap	24.00	29.02	696.48		15.63	375.12		15.63	375.12		15.63	375.12	
Metal from ore	12.00				2.12	25.44		2.12	25.44		2.32	27.84	
Pure manganese from 80 per cent. ferro	162.50	0.142	23.08		0.189	30.71		0.162	26.33		0.055	8.94	
Gross metallic mixture			$1,158.18	$28.32		$1,245.15	$29.39		$1,240.57	$29.14		$1,224.85	$28.86
Heavy scrap recovered	$ 24.00	0.446	$ 10.70		0.467	$ 11.21		0.467	$ 11.21		0.469	11.26	
Pit scrap recovered	20.00	1.339	26.78		1.403	28.06		1.403	28.06		1.409	28.18	
Net metallic mixture			$1,120.70	$27.40		$1,205.88	$28.47		$1,201.30	$28.22		$1,185.41	$27.93
Limestone	$ 2.00	1.05	$ 2.10		2.94	$ 5.88		2.00	$ 4.00		3.09	$ 6.18	
Fluorspar	23.00	0.134	3.08		0.134	3.08		0.134	3.08		0.134	3.08	
Calcined dolomite	9.00	0.446	4.01		1.12	10.08		1.12	10.08		1.12	10.08	
Coal	7.00	8.53	59.71		10.43	73.01		9.75	68.25		11.04	77.28	
Slag disposal	0.50	1.79	0.90		5.10	$ 2.55		4.01	2.01		5.34	2.67	
Total			$ 69.80	$ 1.71		$ 94.60	$ 2.23		$ 87.32	$ 2.05		$ 99.29	$ 2.34
Total cost			$1,190.50			$1,300.48			$1,288.62			$1,284.70	
Cost per ton of ingots				$29.11			$30.70			$30.27			$30.27

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TABLE 1.—(*Continued*)

Materials Used	Price per Gross Ton	High-manganese Iron Low-silica Ore			Excess Limestone			High-silicon Iron			High-phosphorus Iron		
		Tons	Amount	Cost per Ton	Tons	Amount	Cost per Ton	Tons	Amount	Cost per Ton	Tons	Amount	Cost per Ton
Basic hot metal	$ 28.00	29.02	$ 812.56		29.02	$ 812.56		29.02	$ 812.56		29.02	$ 812.56	
Iron in ferromanganese	28.00	0.005	0.14		0.056	1.57		0.066	1.85		0.057	1.60	
Heavy melting steel scrap	24.00	15.63	375.12		15.63	375.12		15.63	375.12		15.63	375.12	
Metal from ore	12.00	2.32	27.84		2.12	25.44		3.00	36.00		2.56	30.72	
Pure manganese from 80 per cent. ferro	162.50	0.019	3.09		0.225	36.56		0.263	42.74		0.228	37.05	
Gross metallic mixture			$1,218.75	$28.54		$1,251.25	$29.81		$1,268.27	$30.17		$1,275.05	$29.56
Heavy scrap recovered	$ 24.00	0.469	$ 11.26		0.467	$ 11.21		0.476	$ 11.42		0.472	$ 11.33	
Pit scrap recovered	20.00	1.409	28.18		1.403	28.06		1.429	28.58		1.416	28.32	
Net metallic mixture			$1,179.31	$27.62		$1,211.98	$28.88		$1,228.27	$29.22		$1,217.40	$28.63
Limestone	$ 2.00	2.06	$ 4.12		5.21	$ 10.42		6.73	$ 13.46		4.23	$ 8.46	
Fluorspar	23.00	0.134	3.08		0.268	6.16		0.134	3.08		0.134	3.08	
Calcined dolomite	9.00	1.12	10.08		1.12	10.08		1.12	10.08		1.12	10.08	
Coal	7.00	10.33	72.31		11.86	83.02		13.51	94.57		11.60	81.20	
Slag disposal	0.50	4.13	2.07		6.90	3.45		9.38	4.69		6.39	3.20	
Total			$ 91.66	$ 2.15		$ 113.13	$ 2.69		$ 125.88	$ 2.99		$ 106.02	$ 2.49
Total cost			$1,270.97			$1,325.11			$1,354.15			$1,323.42	
Cost per ton of ingots				$29.77			$31.57			$32.21			$31.12

TABLE 2.—*Practice Data of the Different Heats*

	Scrap	Standard Iron High-silica Ore	Standard Iron Low-silica Ore	High-manganese Iron High-silica Ore
Per cent. ingots	91.62	90.58	91.04	90.39
Per cent. heavy scrap	1.00	1.00	1.00	1.00
Per cent. pit scrap	3.00	3.00	3.00	3.00
Per cent. loss	4.38	5.42	4.96	5.61
Tons of ingots	40.90	42.36	42.57	42.44
Hot-metal analysis	C, 4.30; Si, 0.75; P, 0.2; Mn, 1.00; S, 0.04	C, 4.30; Si, 0.75; P, 0.2; Mn, 1.00; S, 0.04	C, 4.30; Si, 0.75; P, 0.20; Mn, 1.00; S, 0.04	C, 4.30; Si, 0.75; P, 0.2; Mn, 2.00; S, 0.04
Hot metal, per cent. charged	35.00	62.05	62.05	61.79
Scrap, per cent. charged	65.00	33.41	33.41	33.27
Iron from ore		4.54	4.54	4.93
Silica in ore		9.29	4.62	9.29
Pounds coal per ton of ingots	467.0	551.0	511.0	583.0
Pounds limestone per ton of ingots	57.0	155.00	105.0	163.0
Pounds pure manganese in ladle per ton	7.8	10.0	8.5	2.9
Residual manganese in bath	0.24	0.20	0.23	0.34
Weight of slag, pounds	4,003.0	11,423.0	8,975.0	11,965.0
Weight of iron in slag, pounds	536.0	1,728.0	1,274.0	1,432.0

	High-manganese Iron Low-silica Ore	Excess Limestone	High-silicon Iron	High-phosphorus Iron
Per cent. ingots	90.92	89.76	88.23	90.11
Per cent. heavy scrap	1.00	1.00	1.00	1.00
Per cent. pit scrap	3.00	3.00	3.00	3.00
Per cent. loss	5.08	6.24	7.77	5.88
Tons of ingots	42.70	41.97	42.04	42.53
Hot-metal analysis	C, 4.30; Si, 0.75; P, 0.2; Mn, 2.00; S, 0.04	C, 4.30; Si, 0.75; P, 0.2; Mn, 1.00; S, 0.04	C, 4.30; Si, 1.75; P, 0.2; Mn, 1.00; S, 0.04	C, 4.30; Si, 0.75; P, 0.7; Mn, 1.00; S, 0.04
Hot metal, per cent. charged	61.79	62.05	60.91	61.48
Scrap, per cent. charged	33.27	33.41	32.80	33.10
Iron from ore	4.93	4.54	6.29	5.41
Silica in ore	4.62	9.29	9.29	9.29
Pounds coal per ton of ingots	542.0	633.0	720.0	612.0
Pounds limestone per ton of ingots	108.0	278.0	359.0	224.0
Pounds pure manganese in ladle per ton	1.0	12.0	14.0	12.0
Residual manganese in bath	0.40	0.16	0.12	0.16
Weight of slag, pounds	9,254.0	15,465.0	20,897.0	14,318.0
Weight of iron in the slag, pounds	940.0	2,536.0	3,624.0	1,918.0

the temperature of the furnace. This physical property might be termed fluidity.

So with a set of factors for determining the amount of ore and lime and the quantity of slag that the charge would yield, the chemical balance sheets for the eight heats were worked out, as well as the thermal balance sheets. Data on how much coal would be required to supply the heat needed to balance the heat generated and heat absorbed were taken from a paper by G. R. McDermott and myself,* as well as the general method of calculating the thermal balance sheets.

*The Thermal Efficiency and Heat Balance of an Open Hearth Furnace. Year Book, Am. Iron & Steel Inst. (1922) 464.

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TABLE 3.—*Combined Practice and Cost Sheet*

Type of Charge	Weight Iron Ore, Pounds	Weight Total Charge, Pounds	Tons of Ingots	Per Cent. Ingots	Residual Mn, Per Cent.	80 Per Cent. FeMn Added, Pounds	Weight of Slag, Pounds	Weight Iron in Slag, Pounds	Weight Manganese in Slag, Pounds	Cost per Ton
Scrap	0	100,000	40.90	91.62	0.24	413	4,003	536	219	$29.11
Standard iron, high-silica ore	4,746	104,746	42.36	90.58	0.20	530	11,423	1,728	504	30.70
Standard iron, low-silica ore	4,746	104,746	42.57	91.04	0.23	453	18,975	1,274	466	30.27
High-manganese iron, high-silica ore	5,188	105,188	42.44	90.39	0.34	158	11,965	1,432	913	30.27
High-manganese iron, low-silica ore	5,188	105,188	42.70	90.92	0.40	54	9,254	940	841	29.77
Excess limestone	4,746	104,746	41.97	89.76	0.16	631	15,465	2,536	544	31.57
High-silicon iron	6,718	106,718	42.04	88.23	0.12	736	20,897	3,624	589	32.21
High-phosphorus iron	5,725	105,725	42.53	90.11	0.16	640	14,318	1,918	541	31.12

TABLE 4.—*Condensed Thermal Balance Sheet*

Type of Charge	Heat Absorbed, Millions B.t.u.	Heat Generated, Millions B.t.u.	Heat to be Supplied in Furnace, Millions B.t.u.	At 17.3 Per Cent. Effective Heat to be Supplied in Gas, Millions B.t.u.	At 10,625 B.t.u. per Pound Total Pounds Coal per Heat	Pounds of Coal per Ton of Ingots
Scrap	46.84	11.71	35.13	203.06	19,111	467
Standard iron, high-silica ore	64.71	21.77	42.94	248.21	23,361	551
Standard iron, low-silica ore	62.04	21.43	40.61	232.06	21,841	511
High manganese iron, high-silica ore	68.74	23.27	45.47	262.83	24,737	583
High-manganese iron, low-silica ore	65.38	22.85	42.53	245.84	23,137	542
Excess limestone	70.67	21.84	48.83	282.25	26,564	633
High-silicon iron	85.84	30.20	55.64	321.61	30,269	720
High-phosphorus iron	74.60	26.77	47.83	276.47	26,021	612

Using these values for material and coal, as well as product and scrap, a comparative cost sheet was made for the various heats, using market quotations of April, 1923, as the base price, with the results shown in Table 1. It will be noted that the high-manganese iron and low-silica ore heat has a price advantage of $0.50 a ton over all the other ore heats. Next come the standard-iron low-silica ore and high-manganese iron high-silica ore heats, which are about on a par. The standard-iron high-silica ore heat costs $0.43 a ton more than the standard-iron low-silica ore, while the excess-limestone, high-silicon iron, and high-phosphorus-iron heats cost from $0.42 to $1.51 a ton more than the standard-iron high-silica ore heat.

For convenience a condensed cost and practice sheet, which shows some of the salient features of the various heats, and a condensed thermal balance sheet, are given as Tables 3 and 4; the complete ones are given as Tables 5-12. (Refer to Feb., 1924, issue.)

The amount of ore required for a 65 per cent iron heat depends largely on whether all of the slag is held in the furnace or whether part of it is run off. In the first case, time is allowed for all the earthy bases to work up and convert the iron and manganese silicates into their oxides and basic silicates; then, by the reducing action of the carbon boil, iron and manganese are free to return to the metal bath. The other practice calls for enough ore to convert the manganase and silicon into silicates and the phosphorus into ferrous and ferric phosphate, in which form they are largely removed from the furnace in the run-off slag. The required amounts of ferric oxide in the form of

TABLE 5.—*Scrap, Furnace Charge*

CHEMICAL BALANCE SHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Material	Weight, in Pounds	Per Cent. C	Pounds C	Pounds CO	Per Cent Si	Pounds Si	Per Cent. SiO_2	Pounds SiO_2	Per Cent. P	Pounds P	Per Cent. P_2O_5	Pounds P_2O_5	Per Cent. Mn	Per Cent. MnO	Pounds Mn	Per Cent. S
Basic hot metal	35,000	4.30	1,505		0.75	263		562	0.20	70		160	1.00		350	0.04
Structural steel scrap	65,000	0.20	130						0.01	7		16	0.40		260	0.04
Ore (natural)																
Michigan limestone	2,343						0.34	8	0.006							0.042
Calcined dolomite	1,000						1.32	13	0.004							0.126
Fluorspar	300						1.12	3	0.004							
SiO_2 from furnace structure								100								
Total entering furnace			1,635			263		686		77		176			610	
Total steel in bath	96,616	0.20	193						0.01	10			0.24		232	0.04
Tapping slag, 99.04 per cent	4,003						17.15	686		67	3.83	153		7.07	219	0.25
Total output			193					686		77					451	
Unaccounted for															−159	
Metalloids oxidized			1,442			263				67					378	

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Material	Pounds S	Per Cent. CaO	Pounds CaO	Per Cent. MgO	Pounds MgO	Per Cent. Fe	Pounds Fe	Per Cent. FeO	Pounds FeO	Per Cent. Fe_2O_3	Pounds Fe_2O_3	Per Cent. Al_2O_3	Pounds Al_2O_3	Per Cent. CaF_2	Per Cent. Volume	Per Cent. Moisture
Basic hot metal	14						32,236									
Structural steel scrap	26						64,583									
Ore (natural)																
Michigan limestone	1	54.60	1,279	0.88	21	0.20	5					0.30	7			1.5
Calcined dolomite	1	48.58	486	32.58	326	0.38	4					1.49	11		15.54	
												R_2O_3				
Fluorspar		2.50	8	0.38	1							1.15	3	92.53		
SiO_2 from furnace structure																
Total entering furnace	42		1,773		348		96,828						21			
Total steel in bath	39					99.51	96,142									
Tapping slag 99.04 per cent	10	44.29	1,773	8.67	348		5.36	17.26	691			0.52	21			
Total output	49		1,773		348		96,678						21			
Unaccounted for	+7						−150									
Metalloids oxidized							150									

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ore for each method are shown in the following table,* and are applicable to actual operating conditions. For the sake of simplicity, the costs and thermal and chemical balance sheets shown are based on the first-named practice.

	Per Cent of FE_2O_3	
	No Run-Off	With Run-Off
1 per cent silicon requires	4.32	7.62
1 per cent phosphorus requires	4.30	7.80
1 per cent manganese requires	0.97	0.97
1 per cent carbon requires	3.60	4.44

The metalloids in part of the pig iron may be considered to be eliminated by the oxidizing capacity of the furnace, while those belonging to the remaining quantity of pig iron charged determine the ore requirement. In practice, it is found that a scrap heat composed of 65 per cent light scrap and 35 per cent pig iron melts at about 0.50 per cent carbon. This so-called oxidizing power of a furnace is largely measured by the amount of iron oxide, or scale, formed during the melting down of the scrap. With ore heats, this oxidizing action is somewhat less; and for the cases under consideration was considered to be 10 per cent less than in the scrap heat. So the ferric oxide charged for the standard ore heat will be that required to eliminate the metalloids from 33,000 lb. of pig iron. The requirements for the high-silicon, phosphorus, and manganese iron heats will be the standard ore figure plus the iron oxide needed to eliminate the increased quantity of metalloids charged.

One of the most vital factors in the economical operation of a basic open-hearth furnace is the slag; and on account of improper composition and excessive volumes, the process as a whole suffers very grave losses. While such losses cannot be entirely eliminated, because of lack of ability to forecast accurately the variation in the quantities of acids to be charged, the tendency at all times is to charge an excess of earthy bases to care for the occasional peak of acids. The determination of the quantities of earthy bases to be charged for any given amounts of silica and phosphorus

TABLE 5—Continued

THERMAL BALANCE SHEET

Heat Absorbed

THERMOCHEMICAL CHANGES

Reduction of oxides of iron:
Heat of formation of Fe_2O_3 = 3240
Heat of formation of FeO = 2430

Input:
Fe_2O_3 =
FeO =
Heat of formation:
Fe_2O_3 =
FeO =
Total =

Output:
Tapping slag = FeO = 691 × 2430 = 1.68 × 10_6

Moisture in ore:
Total weight of ore =
Per cent moisture
Total water
Total heat to make steam at 212°
Specific heat of steam = 0.42 + 0.00013 (2800 + 212) = 0.81
Heat in superheat = (2800 — 212)0.81 =
Total =

*Carl Dichmann: "The Basic Open Hearth Steel Process." Tr. by Alleyne Reynolds. D. Van Nostrand Co., New York, 1911.

Decomposition of limestone:
Heat of formation $CaCO_3$ per lb. = 772 Btu.
Total limestone = 2343 lb.
Total heat required = 2343 × 772 = 1.81 × 10_6
Moisture 1.5 per cent = 351 lb.
Total heat to make steam = 351 × 1092 = 0.38 × 10_6
Heat in superheat = 351 × (2800 — 212) × 081 = 0.74 × 10_6
Total = 1.12 × 10_6

Decomposition of improperly burned dolomite:
Total weight of dolomite = 1000
Volatile = 15.54 per cent = 155
Assumed 98 per cent = 152 exists as CO_2
To drive off CO_2 = 1756 Btu. per lb.
Total heat to drive off CO_2 = 1756 × 152 = 0.27 × 10_6

THERMOPHYSICAL CHANGE

Hot metal 35,000 lb. Temperature = 2474° F. Tapping temperature = 3080° F. includes emissivity factor
Temperature rise (3080° — 2474°) = 606° F.
Specific heat = 0.2
Heat absorbed = 35,000 × 606 × 0.2 = 4.24 × 10_6
Scrap = 65,000 lb. Temperature = 62° F.
Melting temperature scrap = 2795° F.
Heat required to bring to melting temperature = 65,000 × 2733 × 0.16 = 28.42 × 10_6
Latent heat of fusion = 72 Btu.
Total heat of fusion = 65,000 × 72 = 4.68 × 10_6
Heat to raise to temperature of bath = (3080 — 2795) 65,000 × 0.2 = 3.71 × 10_6
Total heat = 36.81 × 10_6
Total heat in molten slag:
Heat in tapping slag = 4003 × 1066 = 4.27 × 10_6 Btu.
Total heat absorbed = 46.84 × 10_6 Btu.

Heat Generated

Oxidation of carbon, weight = 1442
Heat of formation of CO from C per lb. = 4374 Btu.
Heat generated = 4374 × 1442 = 6.31 × 10_6
Oxidation of manganese, weight = 378 lb.
Heat of formation of MnO = 2984 Btu.
Heat generated = 2984 × 378 = 1.13 × 10_6
Oxidation of silicon, weight = 263 lb.
Heat of formation of SiO_2 = 11,693 Btu.
Heat generated = 11,693 × 263 = 3.08 × 10_6
Oxidation of phosphorus, weight = 67 lb.
Heat of formation of P_2O_5 = 10,825 Btu.
Heat generated = 10,825 × 67 = 0.73 × 10_6
Heat of formation of slag weight = 4003 lb.
Heat of formation of slag = 115 Btu.
Heat generated = 4003 × 115 = 0.46 × 10_6
Total heat generated = 11.71 × 10_6 Btu.

Authorities for Constants Used

THERMOCHEMICAL CHANGES

Iron oxide reduction—Richards.
Decomposition of limestone—U. S. Bureau of Standards.
Oxidation of C, Mn, Si, P—Richards, LeChatelier, Berthelot, Thomson.
Formation of slag, calculated using Richards' values.

THERMOPHYSICAL CHANGES

Specific heat, pig iron—0.1665—Oberhoffer.
Specific heat, soft steel—0.16—Meuther.
Latent heat of fusion, pig iron—Hutter.
Latent heat of fusion, steel—average value—Jetner, Richards, Brisker.
Heat in molten slag—Springorum.

Thermal Balance Sheet

HEAT ABSORBED

Red. of oxides of Fe	=	—1.68
Absorp. moisture of ore		
Decomp. of limestone	=	1.81
Absorp. moist. of limestone	=	1.12
Decomposition of dolomite	=	0.27
Heat in molten slag	=	4.27
Heat added to mixer metal	=	4.24
Heat added to scrap	=	36.81

HEAT GENERATED

Oxidation of C	=	6.31 × 10_6
Oxidation of Mn	=	1.13 × 10_6
Oxidation of Si	=	3.08 × 10_6

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Oxidation of P = $0.73 \times 10_6$
Heat form. slag = $0.46 \times 10_6$
Balance heat to be supplied by combustion of gases in furnace = $35.13 \times 10_6$
Total Btu. $46.84 \times 10_6$

THERMAL EFFICIENCY OF BATH

Thermal efficiency of furnace = 17.3 per cent.
Btu. in gas per pound of coal = 10.625

Total Btu. to be supplied in producer gas = $\frac{35.13 \times 10_6}{0.173}$ = $203.06 \times 10_6$ Btu.

Total coal burned = 19,111 lb.

Heat in superheat = $734 \times (2800 - 212) \times 0.81 = 1.54 \times 10_6$

Total = $2.34 \times 10_6$

Decomposition of limestone:
Heat of formation $CaCO_3$ per lb. = 772 Btu.
Total limestone = 6584
Total heat required = $772 \times 6584 = 5.08 \times 10_6$
Moisture 1.5 per cent = 99
Total heat to make steam = $99 \times 1092 = 0.11 \times 10_6$
Heat in superheat = $2096 \times 99 = 0.21 \times 10_6$
Total = $0.32 \times 10_6$

TABLE 6.—*Standard Iron, High-silica Ore Furnace Charge*

CHEMICAL BALANCE SHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Material	Weight, in Pounds	Per Cent. C	Pounds C	Pounds CO	Per Cent. Si	Pounds Si	Per Cent. SiO_2	Pounds SiO_2	Per Cent. P	Pounds P	Per Cent. P_2O_5	Pounds P_2O_5	Per Cent. Mn	Per Cent. MnO	Pounds Mn	Per Cent. S
Basic hot metal.....	65,000	4.30	2,795		0.75	488		1,039	0.20	130			1.00		650	0.04
Structural steel scrap	35,000	0.20	70						0.01	4			0.40		140	0.04
Chapin ore (natural)	9,170						9.29	852	0.05	5			0.13		12	Tr.
Michigan limestone.	6,584						0.34	22	0.006							0.042
Calcined dolomite...	2,500						1.32	33	0.004							0.126
Fluorspar.....	300						1.12	3	0.004							
SiO_2 from furnace structure.....								100								
Total entering furnace.....			2,865			488		2,049							802	
Total steel in bath..	99,069	0.20	198						0.01	10			0.20		198	0.04
Tapping slag, 100.61 per cent.....	11,423						17.94	2,049		129	2.58	295		5.69	504	0.25
Total output.....			198					2,049		139					702	
Unaccounted for....															−100	
Metalloids oxidized.			2,667			488				129					604	

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Material	Pounds S	Per Cent. CaO	Pounds CaO	Per Cent. MgO	Pounds MgO	Per Cent. Fe	Pounds Fe	Per Cent. FeO	Pounds FeO	Per Cent. Fe_2O_3	Pounds Fe_2O_3	Per Cent. Al_2O_3	Pounds Al_2O_3	Per Cent. CaF_2	Per Cent. Volume	Per Cent. Moisture
Basic hot metal.....	26						60,911									
Structural steel scrap.	14						34,772									
Chapin ore (natural).		1.60	147	2.64	242	51.76	4,746	1.18	108	72.64	6,661	1.10	101		3.15	8.00
Michigan limestone..	2	54.60	3,595	0.88	58	0.20	13					0.30	20			1.50
Calcined dolomite....	5	48.58	1,215	32.58	815	0.38	10					1.49	37		15.54	
Fluorspar.....		2.50	8	0.38	1							1.15	3		92.53	
SiO_2 from furnace structure.....																
Total entering furnace	47		4,965		1,116		100,452						161			
Total steel in bath....	40						98,624									
Tapping slag, 100.61 per cent.....	29	43.46	4,965	9.77	1,116		1,728	19.51	2,229			1.41	161			
Total output.....	69		4,965		1,116			100,352					161			
Unaccounted for.....	+22							−100								
Metalloids oxidized..								100								

TABLE 6—Continued

THERMAL BALANCE SHEET

Heat Absorbed

THERMOCHEMICAL CHANGES

Reduction of oxides of iron:
Heat of formation of Fe_2O_3 = 3240 Btu.
Heat of formation of FeO = 2430

Input:
Fe_2O_3 = 6,661
FeO = 108
Heat of formation:
$Fe_2O_3 = 6661 \times 3240 = 21.58 \times 10_6$
$FeO = 108 \times 2430 = 0.26 \times 10_6$
Total = $21.84 \times 10_6$

Output:
Tapping slag = FeO = $2229 \times 2430 = 5.42 \times 10_6$
Moisture in ore
Total weight of ore = 9170
Per cent moisture = 8
Total water = 734
Total heat to make steam at 212° = $734 \times 1092 = 0.80 \times 10_6$
Specific heat of steam = $0.42 + 0.00013 \times (2800 + 212) = 0.81$

Decomposition of improperly burned dolomite:
Total weight of dolomite = 2500 lb.
Volatile = 15.54 per cent = 389 lb.
Assumed 98 per cent = 381 exists as CO_2
To drive off CO_2 = 1756 Btu. per lb.
Total heat to drive off $CO_2 = 1756 \times 381 = 0.67 \times 10_6$

THERMOPHYSICAL CHANGES

Hot metal = 65,000 lb. Temperature = 2474° F. Tapping temperature = 3080° F. includes emissivity factor
Temperature rise (3080° − 2474°) = 606° F.
Specific heat = 0.2
Heat absorbed = $65,000 \times 606 \times 0.2 = 7.88 \times 10_6$
Scrap = 35,000 lb. Temperature = 62° F.
Melting temperature scrap = 2795° F.
Heat required to bring to melting temperature = $35,000 = 2,733 \times 0.16 = 15.30 \times 10_6$
Latent heat of fusion = 72 Btu.
Total heat of fusion = $35,000 \times 72 = 2.52 \times 10_6$
Heat to raise to temperature of bath = $(3080 - 2795)\ 35,000 \times 2.00 \times 10_6$
Total heat in molten slag:
Heat in tapping slag = $11,423 \times 1066 = 12.18 \times 10_6$ Btu.
Total heat absorbed = $64.71 \times 10_6$ Btu.

(Continued on Page 71)

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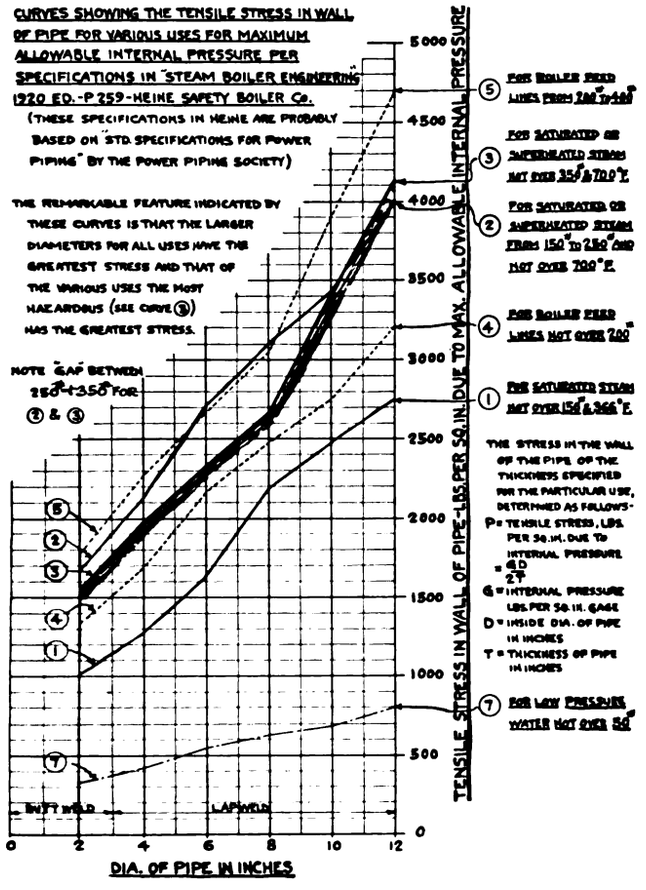
Spacing of Pipe Supports and Hangers

By FRANKLIN H. SMITH*

IN designing piping the problem of supporting the piping always arises. The problem is to determine the proper spacing of the supports or hangers for any particular size and thickness of pipe under the conditions of the installation, as to internal pressure, weight of contents, etc. None of the handbooks, textbooks, catalogs, etc., treat of this important subject so far as the writer is aware. The criterion for spacing of hangers or supports is the permissible tensile stress in the pipe caused by the beam action or the vertical reflection of the piping as a measure of stiffness as a beam.

(1) From the "Curves showing the tensile stress in wall of pipe . . . . . " (Fig. 1) it is evident that a tensile stress as great as 4,000 lbs. per sq. in. is permissible in lap welded steel pipe when used

FIG. 1



for high pressure steam (see curves 2 and 3 for 12-in. dia.), from which it seems reasonable to conclude that 4,000 lbs. per sq. in. is permissible for less hazardous uses such as water, oil, air, etc. This gives $\frac{50000}{4000} =$ 12½ as a factor of safety for a maximum fiber stress of 50,000 lbs. for use in Barlow's formula, p. 224, 1913 ed., National Tube Company's Hand Book.

(2) For butt welded steel pipe the maximum fiber stress is given in National Tube Company's Hand Book, 1913 ed., p. 224, as 40,000 lbs.; $4{,}000 \times \frac{40000}{50000}$ = 3200 lbs. per sq. in. as the permissible stress for butt welded steel pipe proportional to 4,000 lbs. per sq. in. for lap welded steel pipe, giving also a factor of safety of $\frac{40000}{3200} = 12\frac{1}{2}$ for butt welded steel pipe.

(3) In spacing pipe supports and hangers the total stress due to the internal pressure and bending moment should not exceed the permissible stress which has been concluded to be 4,000 lbs. per sq. in for lap welded steel pipe and 3,200 lbs. per sq. in for butt welded steel pipe.

(4) The total stress due to internal pressure and bending moment is the "resultant" of the stress due to the internal pressure and the stress due to the bending moment, and is determined as follows:

$$R = \sqrt{P^2 + S^2}$$

= resultant of "P" and "S".
P = stress due to internal pressure.
S = stress due to bending moment.

$$= \sqrt{R^2 - P^2}$$

(5) P = tensile stress, lbs. per sq. in., due to the internal pressure

$$= \frac{GD}{2T}$$

G = internal pressure, lbs. per sq. in., gauge.
D = inside dia. of pipe, inches.
T = thickness of pipe, inches.

(6) L = distance, inches, between pipe supports or pipe hangers.

$$= \sqrt{\frac{96SQ}{W}}$$ (See note "b," this item.

Note—Calculate "L" and check for "d." If "d" is too great, decrease "L" to make "d" equal to or less than L ÷ 360.

Q = section modulus of the pipe section between bottom of perfect thread and inside of pipe. (See Note "a," this item.)

$= \frac{I}{C}$ in which "C" is the distance from the neutral axis to the extreme fiber; therefore "Q" may be determined from "I" (see note at "I") by dividing by the radius of the outside of the section, using the table on p. 424, etc., of National Tube Company Hand Book, 1913 ed., to find "I."

S = tensile stress, lbs. per sq. in., due to bending movement.

$= \frac{WL^2}{96Q}$ (See Note "b," this item.)

W = total dead and live load of pipe and contents per lin. ft.

d = deflection in inches (which should not exceed 1/360 of the span).

*National Tube Company.

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$= \frac{W_2 L^3}{77EI}$ (See Note "b," this item.)

W_2 = total load, pounds.
$= \frac{WL}{12}$

E = modulus of elasticity, lbs. per sq. in.
= 29,000,000 for steel tubing. (See National Tube Company Hand Book, 1913 ed., p. 257.)

I = moment of inertia of pipe section between bottom of perfect thread and inside of pipe. (See Note "a," this item.)

NOTES—"a"—The section modulus and deflection is taken of the moments of inertia of two solid bars whose outside diameters correspond to the o.d. and i.d. of the hollow cylinder; therefore "I" for pipe sections may be determined by means of the table on p. 424, etc., of National Tube Company's Hand Book, 1913 ed.

Note—"a"—The section modulus and deflection is taken at and for the bottom of the perfect thread because a pipe joint may be located near the point of maximum bending moment, that is, near the center between the supports or near the supports. Theoretically the pipe joints should be located between the supports at the point of contra-flexure or no bending moment (see "b"). Also the bottom of the perfect thread of screwed pipe is taken, as this is considered to give as small a section modulus and deflection as for any other type of joint such as riveted flanges, etc., and for the bolted flanged joint.

"b"—"L" and "S" are for a simple beam supported at the ends and uniformly loaded, as this gives a greater bending moment and deflection than for a continuous beam and results in closer spacing of the pipe supports or hangers. (The bending moment and deflection of a continuous beam with many supports is difficult of determination.)

If the installation has also a concentrated load between the pipe hangers or supports, such as a valve or a connecting line, then the additional equivalent uniform load will have to be determined and added to the actual uniform load for the value of "W"; also the deflection caused by the concentrated load will have to be determined for at the concentrated load and at the center of the span and added to the deflection caused by the uniform load at these points. The sum of these two deflections at the center of the span or at the point of concentrated load, whichever is the greater, is the one to be used as "d."

(7) Example applying the preceding:

(a) Assume an 8-in. dia. low pressure water line (water not over 50 lbs. pressure). The specifications (Heine, p. 260) call for pipe weighing 28.55 lbs. per lin. ft., of which the wall thickness is 0.322 in., the inside dia. 7.981 in., and the outside dia. 8.625 in. (See National Tube Company Hand Book, 1913 ed., p. 22.) from which

$$P = \frac{GD}{2T} = \frac{50 \times 7.981}{2 \times .322} = 620 \text{ lbs. per sq. in.}$$ (See "5".)

$S = \sqrt{R^2 - P^2} = \sqrt{4000^2 - 620^2}$
= 3950 lbs. allowable stress due to bending moment. (See "1" and "4.")

(b) Pipe 2½ in, dia. and up has 8 threads per in., the depth of which are 0.1 in. (See National Tube Company Hand Book, 1913 ed., p. 22 and 209), from which

TABLE OF TENSILE STRESS & DEFLECTION FOR STANDARD STEEL PIPE FOR VARIOUS SPACINGS OF HANGERS OR SUPPORTS - PIPE FILLED WITH WATER

		SPACING OF SUPPORTS OR HANGERS																					
		8'-0"		10'-0"		12'-0"		14'-0"		16'-0"		18'-0"		20'-0"		22'-0"		24'-0"		26'-0"		28'-0"		30'-0"	
$\frac{1}{360}$ SPAN =		.266"		.333"		.400"		.466"		.533"		.600"		.666"		.733"		.800"		.866"		.933"		1.00"	
SIZE	THICKNESS	S	d	S	d	S	d	S	d	S	d	S	d	S	d	S	d	S	d	S	d	S	d	S	d
¾	.113	3807	.261	5950	.636	8565	1.32																		
1	.133	3281	.179	5125	.436	7380	.904	10050	1.67																
1¼	.140	2555	.107	3990	.261	5745	.542	7820	1.00	10220	1.71														
1½	.145	2167	.079	3385	.192	4875	.398	6635	.737	8665	1.26	10970	2.01												
2	.154	1643	.047	2565	.115	3690	.239	5025	.442	6560	.754	8305	1.21	10250	1.84										
2½	.203	1438	.034	2245	.084	3235	.174	4405	.323	5750	.550	7280	.882	8985	1.34	10875	1.97								
3	.216	1174	.023	1835	.056	2640	.115	3595	.214	4695	.364	5945	.583	7340	.889	8880	1.30	10565	1.84						
3½	.226	1008	.017	1575	.041	2270	.086	3090	.159	4035	.272	5105	.435	6300	.664	7625	.972	9075	1.38	10650	1.90				
4	.237	884	.013	1380	.032	1990	.067	2710	.123	3540	.211	4480	.337	5530	.514	6690	.753	7960	1.07	9345	1.47	10840	1.98		
4½	.247	782	.010	1220	.026	1760	.053	2395	.098	3130	.167	3960	.268	4890	.408	5915	.597	7040	.846	8265	1.17	9585	1.57	11000	2.07
6	.280	566	.006	885	.014	1275	.028	1735	.053	2265	.090	2865	.144	3535	.220	4280	.321	5095	.454	5975	.625	6930	.841	7955	1.11
8	.277	480	.004	750	.009	1080	.018	1470	.034	1920	.058	2430	.094	3000	.143	3630	.209	4320	.296	5070	.407	5880	.548	6750	.722
10	.279	433	.003	675	.006	975	.013	1325	.024	1730	.041	2190	.065	2700	.100	3270	.146	3890	.206	4565	.284	5295	.382	6080	.504
12	.330	338	.002	530	.004	760	.009	1035	.016	1355	.027	1710	.044	2115	.066	2560	.097	3045	.138	3575	.190	4145	.255	4755	.336

$S = \frac{WL^2}{96Q}$ = FIBER STRESS IN LBS. PER SQ. IN. AT CENTER OF SPAN

$d = \frac{W_2 L^3}{77EI}$ = GREATEST DEFLECTION IN INCHES AT CENTER OF SPAN

W = TOTAL DEAD & LIVE LOAD OF PIPE AND CONTENTS PER LIN. FT.

L = DISTANCE IN INCHES BETWEEN PIPE SUPPORTS OR HANGERS.

Q = SECTION MODULUS OF THE PIPE SECTION BETWEEN THE BOTTOM OF THE LAST PERFECT THREAD AND INSIDE OF PIPE

W_2 = TOTAL LOAD IN POUNDS FOR LENGTH "L" = $\frac{WL}{12}$

E = 29,000,000 = MODULUS OF ELASTICITY

I = MOMENT OF INERTIA OF THE PIPE SECTION BETWEEN THE BOTTOM OF THE LAST PERFECT THREAD AND INSIDE OF PIPE

NOTE: THE ABOVE TABLE IS CALCULATED FOR STANDARD PIPE - IN CASE OF MORE THAN ONE THICKNESS, AS FOR 8", 10" & 12", THE THINNEST PIPE WAS USED.

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$$Q = .098\,\frac{[(8.625 - 2 \times 1)^4 - 7.981^4]}{(8.625 - 2 \times 1)}$$

$$= .098\,\frac{(8.425^4 - 7.981^4)}{8.425}$$

$$= .098\,\frac{981}{8.625} = 11.4 \text{ (See "6".)}$$

$$I = .049\ [(8.625 - 2 \times .1)^4 - 7.981^4]$$
$$= .049\ (8.425^4 - 7.981^4).$$
$$= .049 \times 981 = 48 \quad \text{(See "6".)}$$

(c) 8-in. dia. pipe with couplings weighs 25 lbs. per lin. ft. and contains 0.35 cu. ft. per lin. ft. (See National Tube Company Hand Book, 1913 ed., p. 22 and 301.)

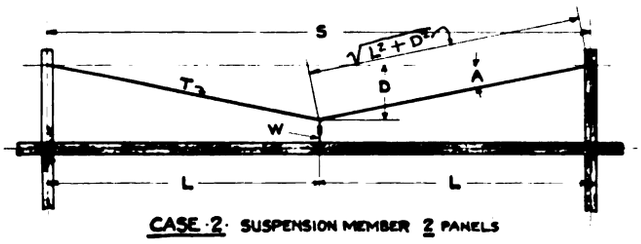
Water weighs 62.5 lbs. per cu ft.

$62.5 \times .35 = 22$ lbs. per lin. ft. weight of water.

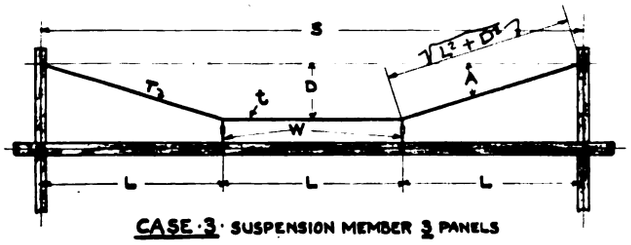
$25 + 22 = 47$ lbs. per lin. ft. total weight of pipe and water.

DESIGN OF SUSPENSION MEMBER FOR PIPE HANGERS

CASE 1 · NO SUSPENSION MEMBER



CASE 2 · SUSPENSION MEMBER 2 PANELS



CASE 3 · SUSPENSION MEMBER 3 PANELS

D = $\frac{S}{10}$ (THE RECOMMENDED VALUE)
W = LOAD ON ONE HANGER
T = TENSION IN SUSPENSION MEMBER AT SUPPORTS (FOR 2 OR 3 PANELS)
= $\frac{W\sqrt{L^2+D^2}}{D}$ NOTE:- $\frac{\sqrt{L^2+D^2}}{D}$ WILL BE CLOSE ENOUGH FOR ALL PRACTICAL PURPOSES IF FOUND ACCURATELY GRAPHICALLY.
t = TENSION IN SUSPENSION MEMBER AT CENTER (FOR 3 PANELS)
= $\frac{WL}{D}$

$$L = \sqrt{\frac{96SQ}{W}} = \sqrt{\frac{96 \times 3950 \times 11.4}{47}}$$

= 303 in. = 25 ft. 3 in., say 25 ft. 0 in. max. spacing of supports or hangers. (See "6".)

$$\frac{303}{360} = .95 \text{ allowable deflection.} \quad \text{(See "6".)}$$

$$d = \frac{W_2L^3}{77EI} = \frac{47 \times 24 \times 303^3}{77 \times 29{,}000{,}000 \times 48}$$

$$= \frac{47 \times 24 \times 27{,}820{,}000}{77 \times 29{,}000{,}000 \times 48}$$

= .29 in. This is less than the allowable deflection so that pipe supports or hangers spaced 25 ft. c.c. are satisfactory for this installation.

(d) If this pipe were under 100 lbs. pressure

P = 1240

S = 3800

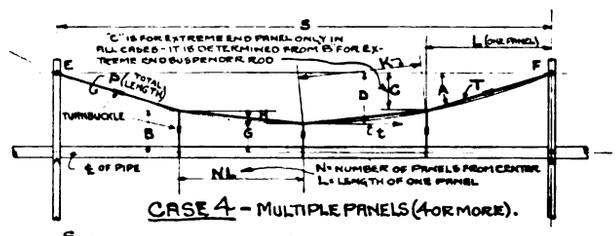
$$L = \sqrt{\frac{96SQ}{W}} = \sqrt{\frac{96 \times 3800 \times 11.4}{47}}$$

= 297 in. = 24 ft. 9 in., say 25 ft. 0 in., same as for 50 lbs. water pressure.

DESIGN OF CATENARY SUPPORTS FOR PIPING ETC.

THE FOLLOWING IS BASED UPON THE ASSUMPTION THAT THE CURVE MADE BY THE SUSPENSION MEMBER IS A PARABOLA, THIS IS NOT STRICTLY CORRECT AS THE ACTUAL CURVE OF THE SUSPENSION MEMBER LIES BETWEEN A PARABOLA AND A CATENARY; FOR MAKING THE DRAWING AND FOR ESTIMATING PURPOSES, THE SUSPENSION MEMBER MAY BE DRAWN AND CONSIDERED AS THE ARC OF A CIRCLE, SINCE THE ACTUAL CURVE OF THE SUSPENSION MEMBER COINCIDES VERY NEARLY WITH AN ARC OF A CIRCLE WHEN D IS $\frac{S}{10}$ OR LESS (AND THE MORE SO AS D BECOMES LESS THAN $\frac{S}{10}$).

NOTE:- IF E-F IS NOT HORIZONTAL THE ANGLE A IS TO BE MEASURED FROM A HORIZONTAL LINE DRAWN FOR THE PURPOSE AT EACH POINT OF SUSPENSION, AS THE TWO ANGLES IN THAT CASE WILL BE UNEQUAL.



CASE 4 - MULTIPLE PANELS (4 OR MORE).

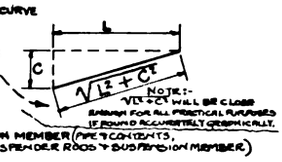
D = $\frac{S}{10}$ (THE RECOMMENDED VALUE)

P = TOTAL LENGTH OF SUSPENSION MEMBER ALONG CURVE
= $2\sqrt{4D^2 + (\frac{S}{2})^2}$ (SEE K)

T = TENSION IN SUSPENSION MEMBER AT SUPPORTS
= $\frac{W}{2} \times \frac{\sqrt{L^2+C^2}}{C} = \frac{W\sqrt{L^2+C^2}}{2C}$

t = TENSION IN SUSPENSION MEMBER AT CENTER
= $\frac{W}{2} \times \frac{L}{C} = \frac{WL}{2C}$

W = TOTAL DEAD & LIVE LOAD CARRIED BY SUSPENSION MEMBER (PIPE & CONTENTS, SUSPENDER RODS & SUSPENSION MEMBER)

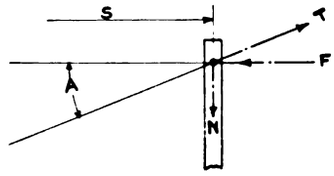


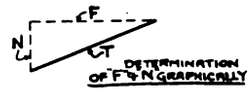
B = LENGTH OF SUSPENDER ROD AT ANY POINT LOCATED AT A DISTANCE "NL" FROM THE CENTER.
= G + H

H = $\frac{4D(NL)^2}{S^2}$

LET K = LENGTH OF SUSPENSION MEMBER BETWEEN TWO ADJACENT SUSPENDER RODS
= $\sqrt{L^2+J^2}$ (SEE P)

J = DIFFERENCE IN LENGTH (OF "B") BETWEEN TWO ADJACENT SUSPENDER RODS.





F = T COS A

N = T SIN A

END SUPPORTS

IN ADDITION TO THE LOAD "N" ON END SUPPORT, THERE IS THE END PANEL REACTION FROM PIPING, ALSO IN CASE OF MORE THAN ONE CATENARY BENT, THE VERTICAL LOAD WILL BE INCREASED AND THE FORCE "F" NEUTRALIZED. IN CASE OF CHANGE OF DIRECTION OF THE CONSTRUCTION, THE TURNING END SUPPORT AT CHANGE OF DIRECTION WILL REQUIRE A DESIGN TO MEET THE CONDITION.

(8) A short practical method of determining the spacing of pipe supports or hangers, for piping 12 in. dia. or less, is to

(a) Calculate "P" (item "5").

(b) Calculate "S" (item "4").

(c) Refer to "Table of Tensile Stress and Deflections for Standard Pipe" (other than X Heavy and XX Heavy pipe installations), then to size of pipe under consideration and find span corresponding to

(Concluded on Page 85)

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Fluorspar: Its Occurrence and Production

History and Geology of This Element Essential to Open Hearth Practice

By A. M. MICHELL*

FLUORSPAR, a comparatively unknown non-metallic mineral, is an essential in the manufacture of open hearth steel, and hence of considerable interest to the steel industry. This mineral is also used to a smaller extent in other industries.

Fluorite, to use its chemical name, has the composition denoted by the formula CaF_2. It is a crystalline, glassy mineral, having a specific gravity of 3.2 and a melting point of 1650 deg. F. While usually colorless, it may at times be found in several different hues; the color has a little significance chemically.

In the United States, fluorspar has been found in Arizona, Colorado, Illinois, Kentucky, New Hampshire, New Mexico, Tennessee and Utah. However, the states of Illinois and Kentucky produce practically all of the domestic fluorspar, the production being about two-thirds in the former state and one-third in the latter. This production is obtained from a region less than 20 miles square, lying along the Ohio River. Recently reported discoveries of fluorspar in the Rocky Mountain States have proven to be of little value, as they are of low grade and the freight rates to any consuming center prohibitive.

In England fluorspar is found rather widely distributed throughout Durham and Derbyshire. It usually occurs as a gangue with lead and zinc ores. For many years the fluorspar was discarded, but the active demand which started about 1890 caused these dumps to be reclaimed. Most of this material was shipped to the United States, and in 1910 the imports of English fluorspar almost equalled domestic production. At present English fluorspar is being mined and sold in the Atlantic seaboard steel producing centers at a price to compete with the home product in spite of a duty of $5.60 per ton.

A few deposits are known in Canada, notably near Trail, British Columbia. This deposit supplies most of the demand on the Pacific Coast.

Germany has supplied high grade fluorspar for a long period, and also mines a considerable quantity of gravel fluorspar for steel making. Mexico has several known deposits of fluorspar, but only one commercial operation, this being in San Louis Potosi. During a scarcity several years ago some imports were made from Africa, but the price was high and quality not very good.

At first the fluorspar was all shipped as lump or gravel without washing; in 1894 the first washed spar was produced. Since that time production has increased with more or less regularity, depending largely on the production of open hearth steel ingots and foreign competition.

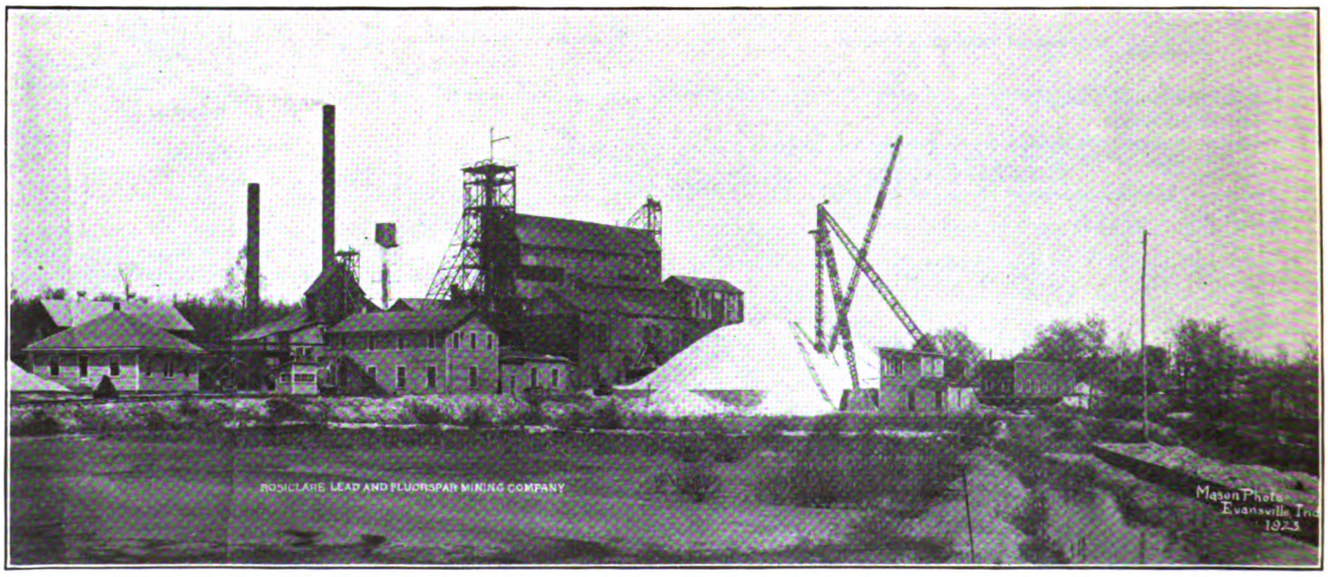
In steel making, the specifications call for a material which will pass through a ¼-inch ring, contain 85 per cent and over of calcium fluorite, 5 per cent or less of silica, and be free from objectionable sulphides, lead and zinc. These limits are pretty closely adhered to, especially during the last several years.

The action of fluorspar in the basic open hearth process is fairly well understood. It renders the slag more fluid, thus making its action more effective in reducing the phosphorous. Recent German investigations also tend to show that fluorite causes a marked decrease in the sulphur content.

Mining in the Kentucky-Illinois fluorspar field was first started in 1835, when a company headed by Andrew Jackson sunk a shaft near Marion, Ky., in search

*Marion, Ky.

Photos by courtesy of E. C. Clark, Superintendent, Rosiclare Lead & Fluorspar Company.



Surface plant of the Rosiclare Lead and Fluorspar Mining Company, the largest producer in the district. The head frame, mill, power plant and storage bin may be seen.

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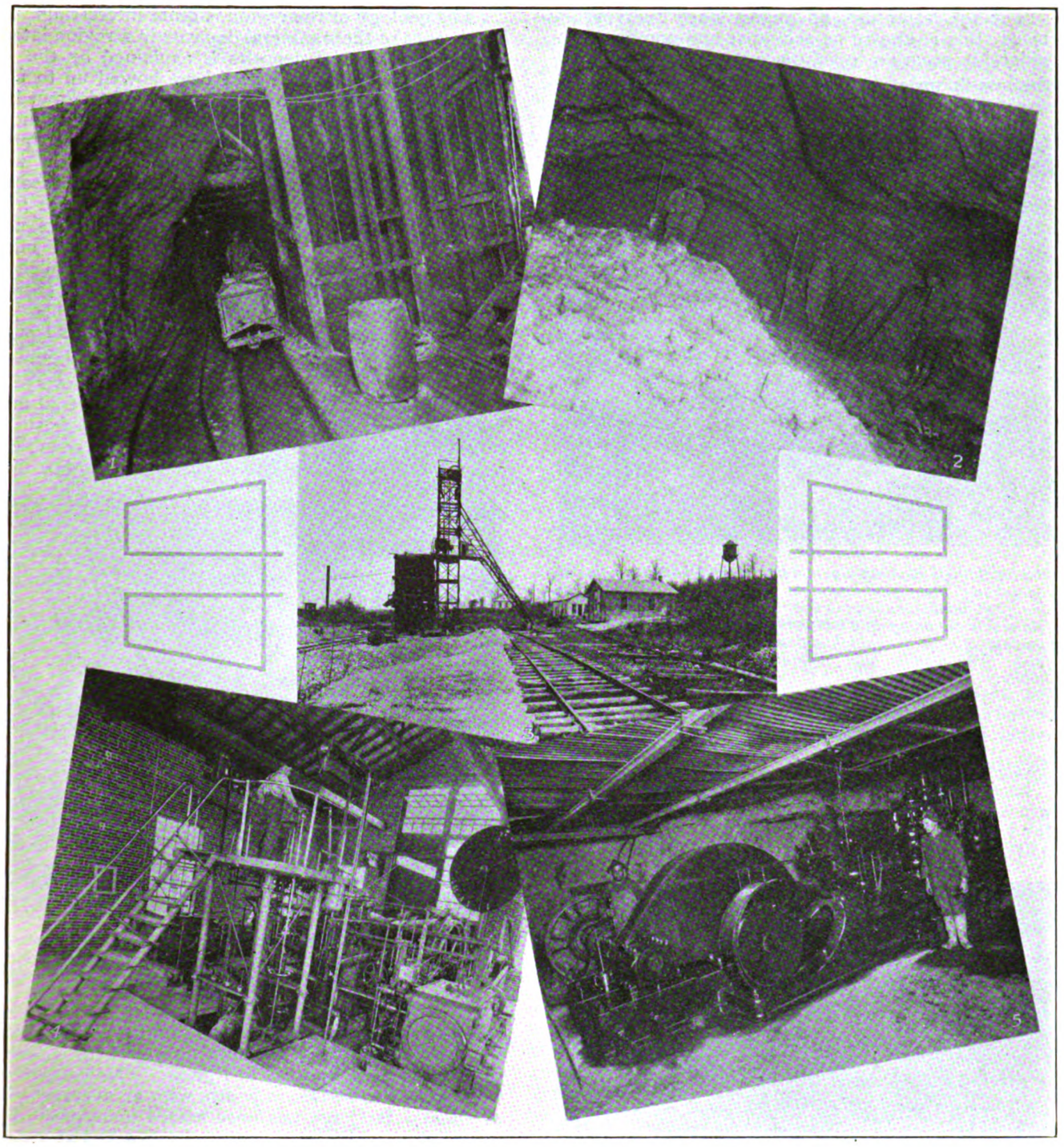

1—Hand tramming the fluorspar on one of the levels. These cars are hoisted to the surface in cages, and there dumped. 2—Scene in top of stope. The men stand on broken fluorspar and drill holes in the vertical vein, which is then shot down. Just enough fluorshap is withdrawn from time to time to give the men room to work. By this method the fluorspar between levels, often one hundred feet apart, is stoped out. Chutes with gates are provided at the bottom for withdrawing the broken ore. 3—Head frame and hoist house for the men and material shaft. No men or mine supplies may be carried down the main shaft. 4—Large steam hoist used for hoisting the ore. Conical drums are used, as may be seen in the illustration. 5—Motor driven pump, used to keep the mine free from water. This pump is installed in a room cut from the rock near the foot of the shaft.

of lead. About 1850 the impression prevailed that the lead ores of the district contained considerable silver, and this occasioned activity. The first flourspar was shipped early in 1870, the mineral being hauled to the Ohio River and loaded in boats. Production continued intermittently for a long period, being about equally divided between Illinois and Kentucky.

In addition to steel making, fluorspar is used in the glass, ceramic and enameling industries. It is essential to the present method of producing aluminum, and is also used in the electrolytic production of lead and antimony. In foundries it is used to produce a more liquid metal and greater freedom from slag, hence cleaner castings. It is also used in the manufacture of carbide, in the manufacture of Portland cement, and in the production of hydrofluoric acid and sodium fluor-

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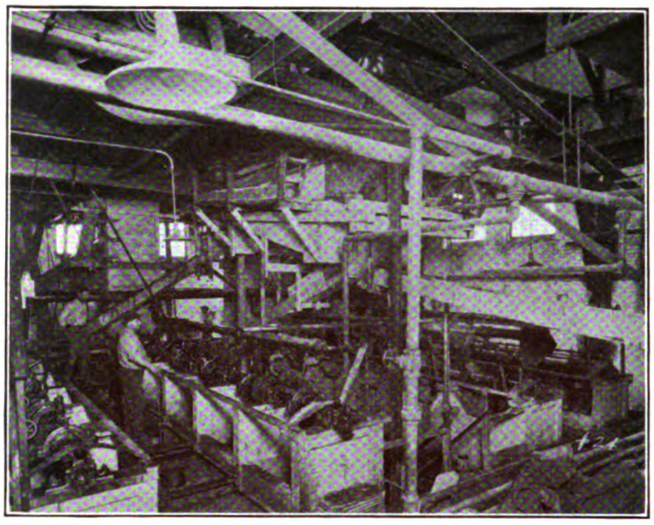
ide. For the latter use, an almost pure fluorspar is required; this is known as acid spar and commands a considerable premium over the commercial grade.

Sodium fluoride has lately been recognized as a very efficient wood preserver, and its use for this purpose is

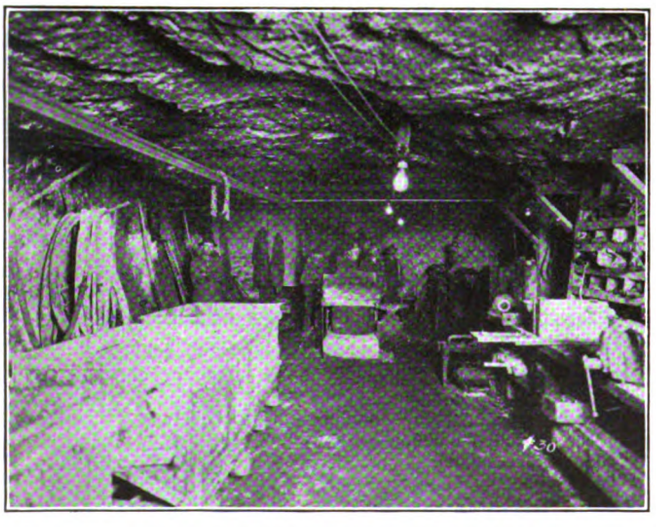


A section of the mill, showing several sets of Harz type jigs in operation. Fluorspar, having a higher specific gravity than the rock which accompanies it, sinks to the bottom of the jig and is drawn off as a hutch product, together with a small amount of lead ore which accompanies the fluorspar in the vein. The lead is later separated from the fluorspar on tables.

expected to increase rapidly. It is said to be superior to either coal tar, creosote or zinc chloride.

Geological Features.

The accompanying map shows the location of the Kentucky-Illinois fluorspar district. A detailed study of the region has been made by the United States and State Geological Surveys. The rock formation consists

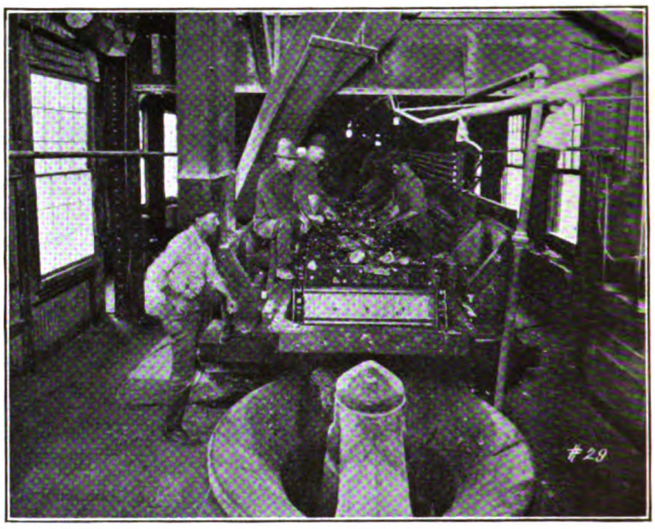


An underground blacksmith shop. Here the large amount of drill steel required for drilling the ore and rock is sharpened, and minor repairs to underground equipment made.

mainly of massive limestone and sandstone beds of Mississippian age. To the north, east and west these beds dip under coal formations of the Pennsylvanian age, while underneath the field, at a depth of about 1,000 feet, are found shales of the Devonian age.

The geology of the region is quite interesting. The occurrence of these mineral deposits in a region largely surrounded by coal deposits is explained by the fact that the rock beds have here been bowed up to form an immense dome. This movement was followed by the intrusion of igneous dikes and further rock movement, causing much faulting and differential setting of large blocks. The resulting fissures which were formed furnished convenient channels for ore bearing solutions from below and these openings were filled with vein forming material. Where conditions were favorable, fluorspar is deposited along with minor amounts of lead and zinc sulphides and a considerable amount of calcite gangue. Some fissures were entirely filled with barite, others with calcite. The theory of the formation is that calcite was first deposited in the fissues, in many cases to be later dissolved and replaced by fluorite.

The accepted extent of this area is about 20 miles north and south and about 15 miles east and west. As might be expected, there is a considerable number of veins, many of which are of minor importance, little



Picking belt and crusher. The large pieces of rock are removed before the ore enters the mill. From the picking belt the ore goes to the gyratory breaker, which reduces it to uniform size.

or no fluorspar having been found in them. The largest vein, which was also the first one worked, is known as the Rosiclare, and lies in Illinois. This vein, nearly vertical, is 6 to 20 feet in width, with an average width of about 7 feet, and has been traced underground for nearly three miles. It is now being worked at a depth of 630 feet. Several subsidiary veins are also worked. The Rosiclare vein has been the principal producer since the field was opened, and furnishes the entire Illinois output.

Another deposit is also worked in Illinois, which is chiefly interesting in that the ore lies in a horizontal position, mineral bearing solutions having replaced a bed of limestone.

In the Kentucky field none of the veins have been developed on the scale found on the Rosiclare vein. Some six main veins are being worked at present. Before the war the low price of fluorspar discouraged any attempt to work the deposits at depth, and at most of the workings the limit of depth was 200 feet. In the last few months, however, diamond drilling on several

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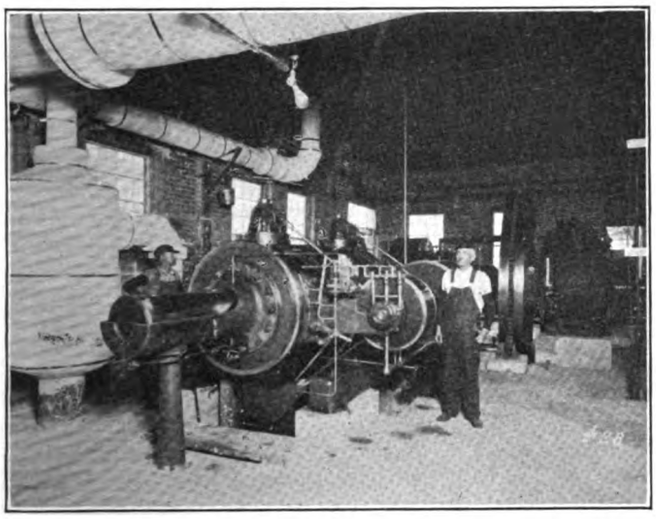
properties indicates that the veins on the Kentucky side contain good spar at greater depths.

Mining Methods.

The equipment used at most of the fluorspar operations is simple, and in most cases crude. Three large mines in Illinois have complete plants, and several well equipped mining plants are under construction or completed in Kentucky. The usual method of winning the ore consists of driving vertical shafts, usually in the country rock near the vein, running cross cuts and levels in the vein at intervals of 50 to 75 feet. The



The power house, showing uniflow engine driving generators. A considerable amount of electric power is required for the varied operations at the mine.

intervening ore is then stoped out, either by a filled stope system, or where the rock walls are not good, by the use of square sets.

The milling equipment is also fairly simple, and consists of crushers, jigs, lead tables and screening equipment. Jigs of the Harz type are usually used.

Production and Imports.

The earliest record of production of fluorspar in the United States is in 1883. Since that time the production has been as follows:

1883	4,000	tons
1892	12,250	"
1900	18,450	"
1905	57,385	"
1910	69,247	"
1915	136,391	"
1918	263,817	"
1920	186,770	"

Shipments decreased largely in 1921, due to the depression in the steel business and large stocks on hand.

English production is said to average about 50,000 tons per year, of which a considerable portion is shipped to this country. German production is small.

The curve of production corresponds closely to that of steel ingot production as shown in the accompanying figure.

Present Situation.

The low prices for fluorspar which prevailed before the war are undoubtedly a thing of the past. Imports from the waste dumps of England, low production costs and the robbing of shallow deposits, all combined to keep the price at a low level. The present tariff of $5.60 a ton, combined with increased freight rates and mining costs, have brought the price of English fluorspar to a higher level. It is hard to estimate the cost of producing domestic fluorspar, but a price below $16.00 per ton would cause many producers to cease operations, and the price canot go much below this figure. The prospect for new supplies of fluorspar is remote. During the war period the insistent demand for fluorspar caused prices of $35.00 to $50.00 per ton, and justified extreme activity. Yet not a new deposit of any consequence was found, the increased supply coming from old dumps and the exhaustion of existing reserves. Limited reserves and increasing demand and price have caused a number of steel producers to enter the field. The largest steel company in the country recently took over practically all the prospects in one of the best Kentucky districts, and other companies have either secured property, or are negotiating for some. It is regarded as only a matter of time until the small producer will be eliminated, all the property being held by the consumers or large producing companies.

DEVELOPMENTS IN ELECTRICAL INDUSTRY

(Continued from Page 28)

wave flows through one meter and the other one-half wave flows through the other meter. In this way the current supplied to each conductor is measured separately.

Electrically Operated Flow Meters.

A type of electrically operated flow meter with many new characteristics was developed for accurately measuring the total flow of steam, water, gas, oil, etc., through pipes and so furnishing information of great value in the economical management of any manufacturing industry or central station. It does not supersede the mechanically operated flow meter, but is simply an addition to existing types.

Due to the electrical principle of operation, the indicating curve drawing and disintegrating instruments can be located at any distance away from the pipe where the flow is being metered and the instruments can be either separated, grouped or duplicated.

Carrier Current.

The carrier current system of telephony, which effects communication by means of high frequency currents superimposed on the power conductors of transmission lines, was applied over greater distances than heretofore by the prdouction of a 250-watt transmitter and receiving equipment. The rating of the previous outfit was 50 watts and its maximum range in an actual installation was 88 miles.

With the larger equipment service is now being maintained over distances up to 116 miles, with apparatus under construction for communication over 138 miles. The progress already made in this new method of telephoning is indicated by the fact that it has already been adopted for 70 transmission lines with an aggregate length of over 2,000 miles.

Switching Apparatus.

The developments in switching apparatus consisted largely in the improvement of existing designs rather than in bringing out strictly new types of apparatus. Both horizontal and vertical isolated phase arrangements were worked out in detail for several important installations and the application of breakers to removable trucks was extened to include motor operated breakers with separating chambers.

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Gas Producer Practice*

By WALDEMAR DYRSSEN†

SO much has been written about gas producers, and so many investigations made in the principal steel manufacturing countries of the world, that it would seem that the gasification of coal would be fully understood and that it would be a difficult task to bring up any new points of scientific and practical importance. However, in studying gas producer literature published during the last 20 years, one cannot help discovering that the data given are unsatisfactory in many respects, especially in regard to theory.

Laboratory Experiments.

The now classic experiments by Boudouard, regarding the balance of the system C, CO and CO_2, and by Harris ond others, regarding the system C, H_2O, H. CO and CO_2, cannot be directly applied in gas producer practice. This has been pointed out many times, for instance by Clements, Adams and Haskins‡, who conducted a series of laboratory experiments with CO_2 and H_2O in contact with various kinds of C at various temperatures, velocities and times of contact. They found that, when time of contact was reduced to two or three seconds, only a very small portion of CO_2 or H_2O were decomposed at 1700 deg. to 1900 deg. F. At these temperatures, practically complete decomposition would have been obtained at equilibrium or at long time of contact. They found also that C as coke or anthracite reacted very much more slowly than C as charcoal.

These investigators came to the result that a minimum temperature of 2372 deg. F. (1300 deg. C.) would be required in gas producers for producing low CO_2 gas from air, and a temperature of 2557 deg. F. (1400 deg. C.) for decomposing H_2O fairly completely at a gas velocity of one foot per second. We know that such high temperatures do not exist in ordinary gas producer practice, because practically all ashes from ordinary producer coal fuse at a considerable lower temperature. Actual measurements have shown that the maximum temperature anywhere in the fuel bed does not exceed 2200 deg. F. in ordinary producers blown by air and steam. Moreover, the velocities in ordinary producer practice are very much higher than the highest velocity employed in the laboratory tests.

The gas produced per pound of C gasified by blast in a producer is about 90 to 95 cubic feet at standard condition, at a gasification temperature of 2000 deg. and 1800 deg. F. respectively (see Fig. 8), or about 425 cubic feet at these temperatures. Assuming that, in the case of ordinary coal, 60 per cent is C gasified by blast, and that the gasification zone is one foot deep and that the voids in the bed constitute 25 per cent of the total volume, the following velocities and time of contact can be calculated. The time of contact is, therefore, only a fraction of a second in ordinary gas producers in practice.

TABLE I—GAS VELOCITIES AND TIME OF CONTACT BETWEEN GAS AND COAL IN THE GASIFICATION ZONE FOR LOW AND HIGH RATE OF GASIFICATION.

Coal gasified per hour per square foot in producer	20 lbs.	50 lbs.
Velocity of gas per second	5.7 ft.	14.2 ft.
Time of contact between gas and coal	.176 sec.	.07 sec.

It follows that such tests as these cannot be applied to gas producers any more than the classic equilibrium tests. A few considerations of the conditions in the laboratory experiments will readily explain this. The center of the tube, which was electrically heated from the outside, was filled with carbon and a thermocouple was imbedded in the carbon close to the tube. Pure CO_2 and H_2O were employed. In decomposing these gases with C a great quantity of heat is required, even if the gas were heated up to the temperature of the fuel before coming in contact therewith. This heat must be supplied by conduction through the tube walls and through pieces of carbon to reach into the center of the tube. At a very low velocity this heat can be supplied without appreciably lowering the temperature, but when the velocity is increased, the temperature of the surface of the pieces of carbon or the reacting molecules of C is lowered an unknown amount below the recorded temperature. In a producer, the conditions are entirely different. There, each reacting molecule of C is automatically maintained at a constant temperature, because the heat required to decompose a molecule of CO_2 or H_2O is supplied by a nearby molecule of O_2 oxidizing C to CO_2 or CO. Laboratory experiments in order to be of any value must, therefore, be conducted on the same principle; that is, CO_2 and H_2O must be mixed with a certain amount of O, with or without N, and forced through a carbon bed at different velocities, and the resulting temperature and gas composition determined. For each constant blast mixture, there will be a certain temperature and composition of gas, corresponding to a certain velocity. By a series of experiments with various blast mixtures, a complete balance diagram can be obtained for various velocities.

Heat and Chemical Balance in Producers.

In the absence of such experiments, the only method at present available to determine the balance in ordinary gas producers is to draw conclusions from actual tests on producers or from actual practice. The tests which show the best gasification results give, of course, the best information. It can be assumed that the fuel bed in these tests was more even in temperature, freer from blowholes and otherwise more uniform, that is, in regard to the size of the cake or the coked coal and the percentage of voids in the different parts of the fuel bed, with more uniform distribution of blast and more uniform velocities. However, by carefully sifting data from other tests, much valuable information can also be obtained. The balances that exist in a producer are represented in Figs. 1 and 2. They have been derived by considering a great many gasification tests of various bituminous

*Read before the American Iron and Steel Institute, at New York, May 25, 1923.

†United States Steel Corporation, New York, N. Y.

‡Bulletin No. 7, Bureau of Mines, Essential Factors in the Formation of Producer Gas, 1911.

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coals and coke. The equilibrium balances are also shown in dotted lines. These represent the average results from the investigations mentioned above, and from others (Naumann and Ernst).

The method of representing the balance is somewhat novel. Instead of the usual method of representing the gas in volumes or percentages of volume, the resulting gas is given in per cent by weight. This is more practical for the purposes served by these balances in this paper.

In Fig. 1 is shown the composition of the gas obtained from CO_2 or O_2 in contact with C at various temperatures. At equilibrium the gas contains practically only CO at 1800 deg. F.; while in gas producers the temperature would have to be about 2400 deg. F. for the same result. At equilibrium the gas contains, for example, 20 per cent CO_2 at 1600 deg. F., while in producers the temperature must be about 1900 deg. F. for the same result. If air is used, the gas also contains N, but the relation CO_2 to CO remains the same.

The gas from H_2O and C is shown in Fig. 2. The gas is more complex, as it consists of four items. At equilibrium the decomposition of H_2O is complete at about 2100 deg. F.; in the gas producer the temperature would have to be about 2600 deg. F. At equilibrium the gas contains, for example, 40 per cent H_2O at 1600 deg. F., while in producers the temperature would have to be about 1860 deg. F. for the same result. The proportion of CO_2 to CO is the same as in Fig. 1. The CO_2 increases up to a certain temperature, but decreases at a further increase in temperature. The amount of H by weight in the gas is small and cannot accurately be read direct in the diagram, but can be easily calculated from the oxygen in CO_2 and CO, or per cent H =

$$\frac{.727 \times \text{per cent } CO_2 + .571 \times \text{per cent CO}}{8}$$

The gas producer balance, as shown, would theoretically shift somewhat with the rate of driving the producer. At the lower rate the balance would shift towards equilibrium and vice-versa. However, the shift seems to be very small for rates from 20 to 50 pounds of coal gasified per square foot per hour. At a very high rate or a very slow rate, other conditions set in, which influence the gasification more.

It is evident from such balances as are shown in Figs. 1 and 2 that it is possible to establish heat and chemical balances for C gasified by any gas, whether air, waste gases, combustible gases, H_2O or any combination of gases at whatever temperature these may enter the gasification zone. The total heat input should equal the total heat output at balanced temperature conditions in the gasification zone. If such a heat balance shows excess or deficiency of heat, the gasification temperature will adjust itself until balance is reached. The heat input consists of the following items: sensible heat in C and ash which arrive in the gasification zone preheated to the gasification temperature by the escaping gas; calorific heat in C gasified; and sensible (and calorific heat) in the gas used for gasification. The heat output consists of sensible heat in the gases escaping from the gasification zone at gasification temperature and calorific heat in these gases. With only dry air used for gasification it will be found that theoretically a great surplus of heat is created at low temperatures of gasification. The surplus heat decreases with higher temperature until a temperature above 3000 deg. F. is reached. With preheated air the surplus will be greater. With H_2O used for gasification there will be a large deficiency of heat, which also decreases with increasing temperatures of gasification. With preheated H_2O the deficiency is less. With waste gases containing CO_2, N and often H_2O, the deficiency of heat is also large.

From the balance established one can derive practically everything in connection with the gasification of coal; and it will be established that ideal actual practice compares very closely to conclusions that can be drawn from this balance.

A few of the consequences that follow from a certain gasification temperature are:

In Gasification of C by Air:

1. Proportion of CO_2 to CO in gas.
2. Proportion of C oxidized to CO_2 and C oxidized to CO.
3. Oxygen and air required per pound of C gasified.
4. Proportion of N in gas.
5. Total gas obtained per pound of C gasified.
6. Heat generated per pound of C by oxidation of C to CO_2 and CO.
7. Sensible heat in gas leaving gasification zone per pound of C gasified.
8. Complete heat balance of gasification, including heat per pound of C transferred into calorific heat in gas.
9. Surplus heat generated per pound of C gasified with due consideration for sensible heat in C, ash and in air, if preheated.

In Gasification of C by Steam:

10. Composition of gas.
11. Proportion of C oxidized to CO_2 and C oxidized to CO.
12. H_2O decomposed and H_2 obtained per pound of C gasified.
13. Total H_2O used per pound of C gasified.
14. Percentage of total H_2O decomposed.
15. Total gas obtained per pound of C gasified.
16. Heat generated by oxidation of C to CO_2 and CO, and heat consumed by decomposing H_2O per pound of C gasified.
17. Sensible heat in gas per pound of C gasified.
18. Complete heat balance of gasification, including heat per pound of C transferred into calorific heat in gas.
19. Deficiency of heat per pound of C gasified with due consideration for sensible heat in C, ash and H_2O used.
20. From the surplus heat available in gasification by air and from the heat required in gasification by H_2O can be calculated the percentage of C gasified by air, and that gasified by steam for obtaining constant temperature in the gasification zone.

From this follows further, when gasifying C by air and H_2O at balanced temperatures in the fuel bed:

21. Heat in C transferred into calorific heat in total gas from air and H_2O.
22. Composition of total gas.
23. Analysis of dry gas by volume.
24. Air and H_2O used per pound of C gasified, H_2O per pound of air in blast and corresponding saturation temperature of blast.
25. Efficiency of combustion of gas per pound of C gasified.
26. Temperature of gas after passing through distillation zone in gasifying various coals.

This is an imposing list of conclusions that can be drawn from the curves in Figs. 1 and 2 by simply applying well-known recognized methods based on chemical reactions, heat of formations and sensible heat.

Before entering upon the detailed calculations of the items as outlined above, a definition will be given below of the expression and terms used.

Gasification zone is the zone where the pure C,

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TABLE II—PROPERTIES OF COMBUSTIBLES AND GASES

	Btu. per Cubic Foot Gross	Net	Weight per Cu. Ft. at 62° F., 30" Hg.	Pounds of C per 100 Cubic Feet	Btu. per pound Gross	Net	Specific heats per Pound between 62 Deg. F. and t deg. F.
C to CO ...	....	....	.....	.....	4320	4320	.....
C to CO_2 ..	....	....	.....	.....	14544*	14544*	.....
CO	323.2	323.2	.07375*	.03161	4382	4382	.24 +.0000119t
C_2H_4	1591.3	1491.0*	.07386*	.06331	21545	20186	.38 +.000137t
CH_4	1012.5	912.0*	.04228*	.03171	23948	21571	.55 +.000176t
H	329.1	278.5	.005302*	.....	62028*	52518*	3.40 +.00017t
Air	....	....	.07626*	.....	.....	.....	.233+.000015t
CO_2	....	....	.11660*	.03180	.....	.....	.19 +.00006t
O_2	....	....	.08430*	.....	.....	.....	.21 +.0000104t
N	....	....	.07377*	.....	.....	.....	.24 +.0000119t
H_2O	....	....	.04745*	.....	1056.7*†	.....	.42 +.000103t

Values marked (*) are United States Steel Corporation Standard. The gross and net values per cubic foot of H and gross values per cubic foot for C_2H_4 and CH_4 follow from the (*) values and differ slightly from the standard values, which are for these gases 328, 278, 1591 and 1012, respectively. The values for C and CO are closer to the latest accepted values than the United States Steel Corporation Standard of 324 Btu. per cubic foot of CO. †Latent heat.

derived from the coal, is converted into gases by air, H_2O or other gases supplied from an outside source.

Distillation zone is the zone where the moisture and volatile matters in the natural coal are distilled off as gases leaving C and ashes.

Gasification efficiency is the heat that is transferred into calorific heat in the gas, obtained from the gasification of one pound of pure C, divided by the calorific heat in one pound of C (14,544 Btu.). The gasification efficiency is not the producer efficiency, nor is any account taken therein of the volatile matters in the coals.

Combustion efficiency is the heat that is released by the combustion under certain assumed conditions of the gas obtained from the gasification of one pound of pure C, divided by the calorific heat in one pound of C. This efficiency is not based on the calorific heat in the gas itself, but is the ultimate expression of the efficiency of gasification, as the aim thereof is to release as much as possible of the heat in the C gasified at the place where the gas is burned. Distillation gases from the coal are not considered in this efficiency.

These two efficiencies form a basis for estimating accurately the influence of (1) various temperatures of gasification (2) various gases that can be used for gasifying C; (3) various temperatures of the blast.

In Table 2 are given the values used in the calculations. Gross heat values are also given for completeness. United States Steel Corporation Standards have been used in this table as extensively as possible. Specific heats of gases are from Richards and LeChatelier.

In all calculations, net heat values for H, and gases containing H, have been used throughout. It is believed that a comparison between combustible gases on a gross basis is not possible, or at least extremely complicated. It is only the heat that the furnace can possibly utilize that can form a basis for a comparison between, for example, gas with a high CO and low H content and a gas with low CO and high H content. This is realized by authorities in all countries, for instance, by Bone and Wheeler in their valuable gas producer paper*, wherein they point out that both gas and coal should be calculated on the net basis.

An Investigation on the Use of Steam in Gas Producer Practice, The Journal of the Iron and Steel Institute, Vol. LXXIII, 1907.

TABLE III—CHEMICAL BALANCE IN GASIFICATION OF C BY DRY AIR AT VARIOUS TEMPERATURES OF GASIFICATION, PROPORTION OF CO_2 AND CO IN GAS FROM FIG. I.

	Gasification temperature in Deg. F. 1600°	1800°	2000°	2200°
From Diagram, Fig. 1:				
CO_2 in gas.....	62.0	34.0	15.0	6.0
CO in gas.....	38.0	66.0	85.0	94.0
Total (per cent)....	100.0	100.0	100.0	100.0
Pounds per lb. C gasified:				
CO_2	1.866	.905	.370	.143
CO	1.146	1.758	2.098	2.242
N	6.698	5.537	4.882	4.615
Total gas.....	9.710	8.200	7.350	7.000
Oxygen	2.012	1.663	1.468	1.385
Air	8,710	7.200	6.350	6.000
C oxidized to CO_2....	.509	.247	.101	.039
C oxidized to CO.....	.491	.753	.899	.961

TABLE IV—CHEMICAL BALANCE IN GASIFICATION OF C BY H_2O AT VARIOUS TEMPERATURES OF GASIFICATION, PROPORTION OF CO_2, CO, H AND H_2O IN GAS FROM FIG. II.

	Gasification temperature in Deg. F. 1600°	1800°	2000°	2200°
From Diagram, Fig. II:				
CO_2 in gas.....	18.6	17.0	10.5	5.0
CO in gas.....	11.4	33.0	59.5	78.3
H in gas.....	2.5	3.9	5.2	6.05
H_2O in gas.....	67.5	46.1	24.8	10.65
Total (per cent)....	100.0	100.0	100.0	100.00
Pounds per lb. gasified:				
CO_2	1.866	.905	.370	.143
CO	1.146	1.758	2.098	2.242
H	.252	.208	.183	.173
H_2O	6.793	2.460	.876	.305
Total gas	10.057	5.331	3.527	2.863
O from H_2O to CO_2 and CO	2.012	1.663	1.468	1.385
H_2O decomposed	2.264	1.871	1.651	1.558
Total H_2O used.....	9.057	4.331	2.527	1.863
Per cent of Total H_2O decomposed	25.1	43.2	65.3	83.6

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For convenient use, a few points on the curves with the principal items calculated in the temperature range most common in gas producers are given in Tables III and IV.

The detailed calculation of heat balances, etc., will not be given here for all the temperatures given above. However, for the benefit of those especially interested one case is given in Table V. The gasification temperature selected is 2000 deg. F.

Items 17 and 19 (see Table VI) are heat deficiencies with H_2O vapor at 62 deg. and 562 deg. F. respectively. These items for the various temperatures of gasification are represented in Fig. 4. The efficiency of gasification is 129.3 per cent, that is, more heat has been stored up in the gas than contained in C, and part of the heat which must be obtained elsewhere is used for that purpose.

A balanced condition in the fuel bed can be calculated from the surplus and deficiencies of heat when gasifying C by air and H_2O respectively and the proportion of C that is gasified by either. The surplus heat in gasifying by air must compensate the deficiency of heat in gasifying by H_2O. These items are calculated in Table VII, also the weight of gases obtained, analysis of the dry gas by volume, efficiency of gasification, etc.

For other temperatures the calculations are the

TABLE V —HEAT BALANCE OF THE GASIFICATION OF C AT 2000° F. BY DRY AIR (POUNDS OF MATERIAL FROM TABLE No. III.

	Item	Pounds	Btu. per pound	Temperature above 62° F.	Specific heat	Total Btu.
Heat available per pound of C gasified:						
C oxidized to CO_2	..	.101	14544	.....	...	1468.9
C oxidized to CO	..	.899	4320	.....	...	3883.7
Total heat from oxidizing C	1	...	....	.....	...	5352.6
Sensible heat in C	..	1.000	....	1938°	.35	678.3
Ash with this C, average	..	.150	....	1938°	.30*	87.2
Total sensible heat	2	...	....	1938°	...	765.5
Total heat available	3	...	....	.....	...	6118.1
Heat absorbed as sensible heat in gas:						
CO_2	4	.370	....	1938°	.31	222.3
CO	5	2.098	....	1938°	.264	1073.4
N	6	4.882	....	1938°	.264	2497.4
Total	7	7.350	....	1938°	...	3793.1
Surplus heat, Item 3 minus Item 7	8	...	....	.....	...	2325.0
Sensible heat in air if preheated to 562° F.	9	6.350	....	500°	.239	758.8
Surplus heat with air preheated to 562° F., Item 8 plus Item 9	10	...	....	.....	...	3083.8
Calorific heat in gas, 14544 minus Item 1	11	...	....	.....	...	9191.4
Per cent of heat in C transferred to calorific heat in gas, Item 11 divided by 14544	12	...	....	.....	...	63.2

*Approximate.

TABLE VI—HEAT BALANCE OF THE GASIFICATION OF C AT 2000° F. BY H_2O (POUNDS OF MATERIALS FROM TABLE No. IV.

	Item	Pounds	Btu. per pound	Temperature above 62° F.	Specific heat	Total Btu.
Heat available, C oxidized to CO_2 and CO same as Item 1, Table V	..	...	....	.....	...	5352.6
Sensible heat in C and Ash, same as Item 2, Table V	..	...	....	1938°	...	765.5
Total heat available	13	...	....	.....	...	6118.1
Heat absorbed as sensible heat in gas:						
CO_2	..	.370	....	1938°	.310	222.3
CO	..	2.098	....	1938°	.264	1073.4
H	..	.183	....	1938°	3.740	1326.4
H_2O	..	.876	....	1938°	.626	1062.7
Total	14	...	....	1938°	...	3684.8
Heat required for decomposing H_2O	15	.183	52518	.....	...	9610.8
Total heat absorbed, Item 14 plus Item 15	16	...	....	.....	...	13295.6
Heat deficiency, Item 16 minus Item 13	17	...	....	.....	...	7177.5
Sensible heat in H_2O if preheated to 562° F.	18	2.527	....	500°	.478	603.9
Heat deficiency with H_2O preheated to 562° F. Item 17 minus Item 18	19	...	....	.....	...	6573.6
Calorific heat in gas, Item 11 plus Item 15	20	...	....	.....	...	18802.2
Per cent of heat in C transferred to calorific heat in gas, Item 20 divided by 14,544	21	...	....	.....	...	129.3

Item 8 in this table is the surplus heat per pound of C gasified by air at 62 deg. F. If the air is preheated or carries sensible heat, the surplus heat will be increased. Item 10 is the surplus heat with air at 562 deg. F. The surplus heat for the various temperatures of gasification is shown by curves in Fig. 3. It falls off rapidly with increasing temperature. The efficiency of gasification or the calorific heat in the gas as compared to heat in C is given in Item 12.

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TABLE VII—HEAT AND CHEMICAL BALANCE OF THE GASIFICATION OF C BY BLAST (AIR+H_2O) AT 2000° F. AT BALANCED CONDITION OF FUEL BED.

	Blast at 62 Deg. Fahrenheit			Blast at 562 Deg. Fahrenheit		
	Item	Reference and Equations		Item	Reference* and Equations	
Surplus heat per pound of C gasified by air, see Table V	..	I 8	2325.0 Btu.	..	I 10	3083.8 Btu.
Heat deficiency per pound of C gasified by H_2O, see Table VI	..	I 17	7177.5 Btu.	..	I 19	6573.6 Btu.
C gasified by H_2O per pound total C gasified	}	I 8	2325.0 Btu.		I 10	
	22	I 8+I 17	.245 lbs.	23	I 10+I 19	.320 lbs.
C gasified by air per pound total C gasified	24	1—I 22	.755 lbs.	25	1—I 23	.680 lbs.
Gas obtained per pound of C gasified, see Tables 3 and 4:						
CO_2 from H_2O and air	..	.....	.370 lbs.	..	.....	.370 lbs.
CO from H_2O and air	..	.....	2.098 lbs.	..	.....	2.098 lbs.
H from H_2O	..	I 22×.183	.045 lbs.	..	I 23×.183	.058 lbs.
H_2O from H_2O	..	I 22×.876	.215 lbs.	..	I 23×.876	.280 lbs.
N from air	..	I 24×4.882	3.686 lbs.	..	I 25×4.882	3.320 lbs.
Total gas	..	.....	6.414 lbs.	..	.....	6.1266 lbs.
Analysis of dry gas by volume:						
CO_2	..	.....	3.52%	..	.....	3.62%
CO	..	.....	31.55%	..	.....	32.42%
H	..	.....	9.43%	..	.....	12.63%
N	..	.....	55.50%	..	.....	51.33%
Total	..	.....	100.00%	..	.....	100.00%
Cubic feet of dry air per pound of C	..	.....	90.10	..	.....	87.60
Btu. per cubic foot	..	.....	128.10	..	.....	140.00
Btu. per pound of C gasified	26	I 11+I 22×I 15	11546.0	27	I 11+I 23×I 15	12266.8
Efficiency of gasification	..	.....	79.40%	..	.....	84.30%
Air per pound of C gasified	..	I 24×6.35	4.794 lbs.	..	I 25×6.35	4.250 lbs.
H_2O used per pound of C gasified	..	I 22×2.527	.619 lbs.	..	I 23×2.527	.809 lbs.
H_2O per pound of air in blast	..	.....	.130 lbs.	..	.....	.188 lbs.

*Reference to items in this and previous tables is indicated by I followed by number of the item.

same. The principal results are plotted as curves. In Fig. 5 is shown the percentage of C gasified by air and H_2O respectively, at 62 deg. and 562 deg. F. temperature of blast. Fig. 6 shows the gasification efficiencies at balanced condition with blast at 62 deg. and 562 deg. F. The highest efficiency lies between 2000 deg. and 2200 deg. F. Below 1800 deg. F. it drops off rapidly.

The composition of the dry gas by volume at various temperatures of gasification is given in Fig. 7 for blast at 62 deg. F. Moisture per pound of C gasified is shown in Fig. 9.

The real efficiency of the gas and of the gasification can only be judged by considering the conditions under which the gas is used, as, for example, in the open-hearth furnace. It will be assumed that the gas is preheated to 1900 deg. F. before entering the melting chamber, the combustion air to 2200 deg. F., and that the waste gases leave the melting chamber at 2900 deg. F. Theoretical amount of air and complete combustion will also be assumed. The calculations for 2000 deg. F. gasifying temperature are given in Table VIII.

The last line in this table gives actual combustion efficiency. This has been calculated in the same manner for other temperatures of gasification and is shown in Fig. 10. As would be expected, there is a maximum efficiency between 2000 deg. and 2200 deg. F. gasification temperature, as in the case of the gasification efficiency, but there is a marked drop of combustion efficiency at low temperatures. Whereas the gasification efficiency drops from 79.4 per cent to approximately 65.4 per cent, or about 14 per cent, when the gasification temperature is reduced from 200 deg. to 1600 deg. F., the combustion efficiency drops from 47.4 per cent to about 18.4 per cent or approximately 29 per cent.

TABLE VIII — HEAT AND CHEMICAL BALANCE IN THE COMBUSTION IN THE OPEN-HEARTH FURNACE OF GAS FROM C GASIFIED BY AIR AND H_2O. BLAST TEMPERATURE 62°F., GASIFICATION TEMPERATURE 2000° F. IN PRODUCER VALUES PER POUND OF C GASIFIED.

	Pounds	Temperature above 62° F.	Specific heat	Total Btu.
Gas obtained per pound of C gasified, see Table VII:				
CO_2	.370	1838	.300	204
CO	2.098	1838	.262	1010
H	.045	1838	3.710	307
H_2O	.215	1838	.610	240
N	3.686	1838	.262	1775
Total gas	6.414	1838	....	....
Calorific heat in gas, Item 26	....	....	....	11546
Total heat in gas	....	....	....	15082
Combustion air	6.750	2138	.257	3709
Total heat available	....	....	....	18791
Waste gases obtained per pound of C:				
CO_2	3.667	2838	.360	3747
N	8.878	2838	.274	6904
H_2O	.619	2838	.712	1251
Total	13.164	2838	....	11902
Heat available in melting chamber	....	....	....	6889
Percentage of heat available in melting chamber of heat in C gasified = 6889 ÷ 14.544	....	....	....	47.4%

(To be Continued)

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SHEET AND TIN PLATE

Most Modern Sheet Mill

Details of the National Enameling & Stamping Company's New 3′ 0″ Mill at Granite City

By E. H. WERNER*

THE Granite City Steel Works of the National Enameling & Stamping Company have erected a new sheet and jobbing mill at Granite City, Ill., that represents the latest practice in the manufacture of sheets.

There are installed six sheet mills with a range in widths up to 48 in. and gauge No. 30 to 10, and one 72 in. jobbing mill which rolls sheets up to and including 60 in. wide and a complete galvanizing department that handles up to and including 54 in. wide sheets.

The United Engineering & Foundry Company, of Pittsburgh, Pa., were retained as engineers for the building of this plant. They maintained an office at the site, together with a complete engineering department.

The actual construction of the plant began on the 12th day of October, 1922, and the first sheets were rolled on September 24, 1923.

*Chief Engineer, National Enameling & Stamping Company, Granite City, Ill.

The prevailing idea in the building of this plant was to provide ample working space, the best of lighting and ventilation, and to insure the product taking the path of least resistance in order that maximum production at lowest cost be attained.

Buildings.

The buildings, four in number, are designated as bar building, furnace building, mill building and warehouse. The buildings are adjacent to each other and are built on common building columns—i.e., there is not any space between them. Maximum lighting is effected by raising or lowering the roofs of the various buildings so that a row of continuous sliding sash encircles each building just below the eaves of the roof. Maximum ventilation is secured by placing ventilators along the entire roof of each the bar building, mill building and warehouse. Each of the buildings is made up of 35 bays at 22 ft. 6 in. giving a total length of 787 ft. 6 in.

The bar building is 43 ft. 0 in. span and is equipped

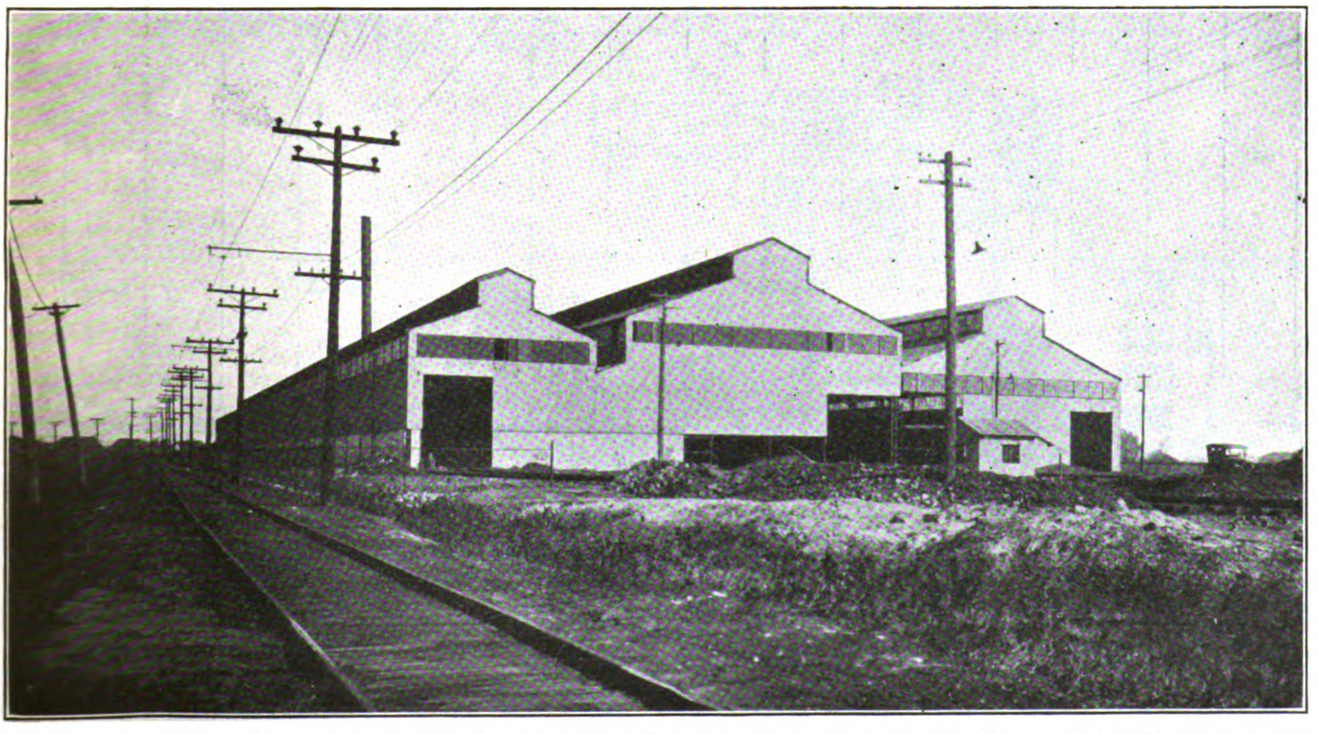

FIG. 1—*An end view of the new sheet mills, showing the four buildings (bar mill, furnace building, mill building proper, and ware house) assembled under one roof. Each building consists of 35 bays at 22 ft. 6 in. with a total length of 787 ft. 6 in.*

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with a runway for a 10-ton 40 ft. 0 in. span electric traveling crane.

The furnace building is 9 ft. 4 in. wide and forms a space between the bar building crane runway and the mill building crane runway for the furnace stacks.

The mill building is 78 ft. 4 in. wide and provides for a 40-ton crane with a 10-ton auxiliary, 75 ft. 0 in. span.

The warehouse building is 78 ft. 4 in. wide and the crane runway designed for a 10-ton 3-motor electric traveling crane.

The bar building is large enough to provide ample storage for cut bars; it will store enough cut bars to operate all of the mills from 30 to 35 days. This is very essential in order to provide against contingencies at the rolling mill and steel plant. All of the coal and ashes are also handled in the bar building. A standard gauge railroad track is provided in the South end of the bar building to facilitate the handling of cut bars, coal and ashes.

The mill building is made exceptionally wide in order to give plenty of space on the catcher's side for taking care of the sheets as they are finished on the mills. The squaring shears are so located that the shearman will work in the mill building while scrap handler will be in the warehouse.

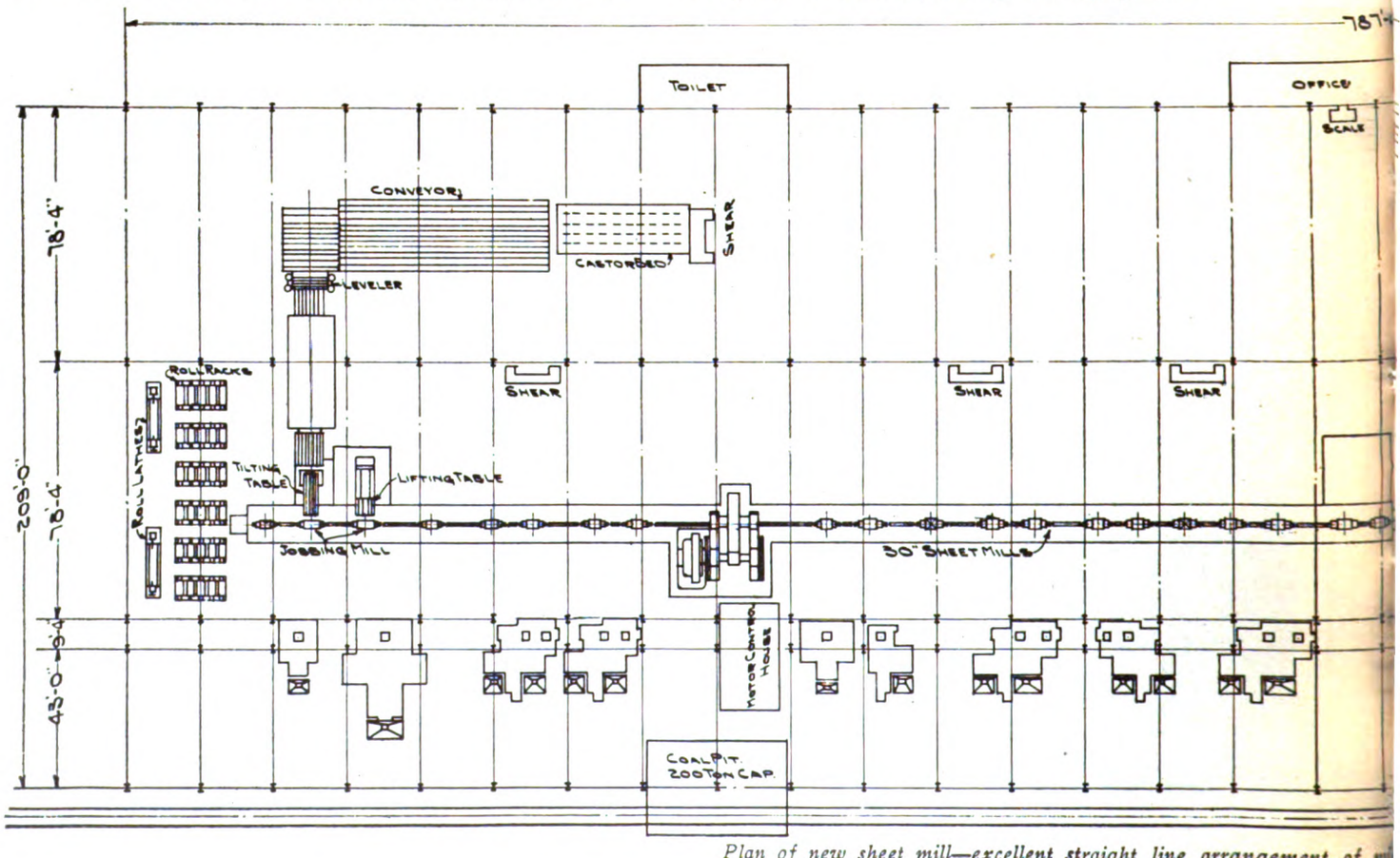
The warehouse has been given much thought and attention. All finished product is so routed that it logically reaches the warehouse in the last operation just prior to shipment. The product of the jobbing mill is under the warehouse crane, ready for loading, after it has been sheared—all black sheets from the mills can be readily transferred with minimum effort to the warehouse crane—all galvanized sheets are deposited under the warehouse crane, ready for bundling and shipping. A depressed shipping track, with a capacity of from nine to 10 cars is provided in the south end of the warehouse, this insuring ideal conditions for loading cars regardless of the weather conditions.

The buildings were designed, fabricated and erected by the Mississippi Valley Structural Steel Company of St. Louis, Missouri.

FIG. 2—*Shows the furnace side of the mills, with view of roll storage in back ground.*

Mill Equipment.

The mills, together with the auxiliary equipment were furnished by the United Engineering & Foundry Company, of Pittsburgh, Pa., and represent the latest design in sheet and jobbing mill equipment.



Plan of new sheet mill—excellent straight line arrangement of m

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The housings are steel castings of the heaviest type. On the south side of the drive are located one 30-in. diameter by 38-in. long roll sheet mill, and three 30-in. diameter by 44 in. long roll sheet mills. The roughing stands on this side of the mill are all spring balanced. Two stands of 26-in. diameter by 54 in. long cold rolls are placed on the end of the train as a drag.

On the north side of the drive and adjacent to it are located two 30-in. diameter by 38 in. long roll sheet mills, one roughing stand of the spring balanced type, and the other of the jump type. Next are located the two high jobbing mills made up of 30 in. diameter by 72 in. long rolls. The roughing rolls are spring balanced, and equipped with motor driven screw down. A lifting table is provided on the catcher's side of the roughing stand, while a tilting table is arranged on the catcher's side of the finishing stand. A conveyor is installed to convey the sheets from the finishing stand to the continuous annealing furnace. A 38 in. x 38 in. drag is located on the end of this train of mills.

Five standard 54 in. doublers, operated with either steam or air, are conveniently located to serve the six sheet mills.

Furnaces.

The furnace equipment, which was furnished by the Tate-Jones Company of Pittsburgh, Pa., consists of five combined sheet and pair furnaces, one single pair furnace and one double sheet furnace for the sheet mills; one continuous slab heating furnace and one large single sheet furnace for the jobbing mills; one Costello continuous blue annealing furnace, and four double box annealing furnaces; one portable blue annealing furnace. All pair furnaces and the continuous slab heating furnace are of the Costello continuous type, arranged with pushers electrically operated. All furnaces with the exception of the open annealing furnace and portable annealer, are designed for coal firing with Jones underfeed stokers. Each stoker is equipped with a coal hopper directly above it, which is filled with coal from a Williams Single Line bucket on the 10-ton crane, thus reduicng to a minimum the

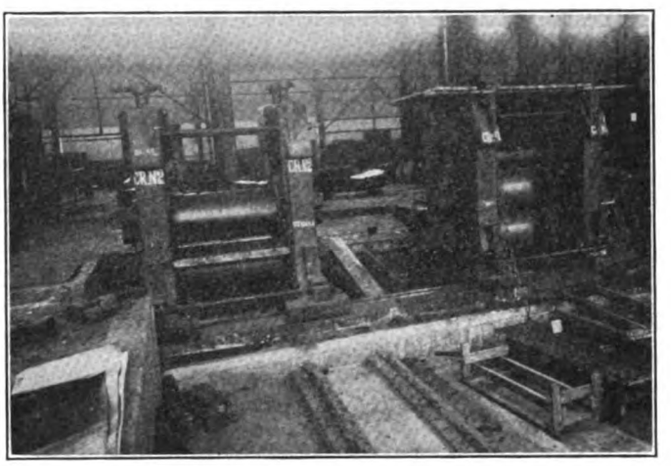
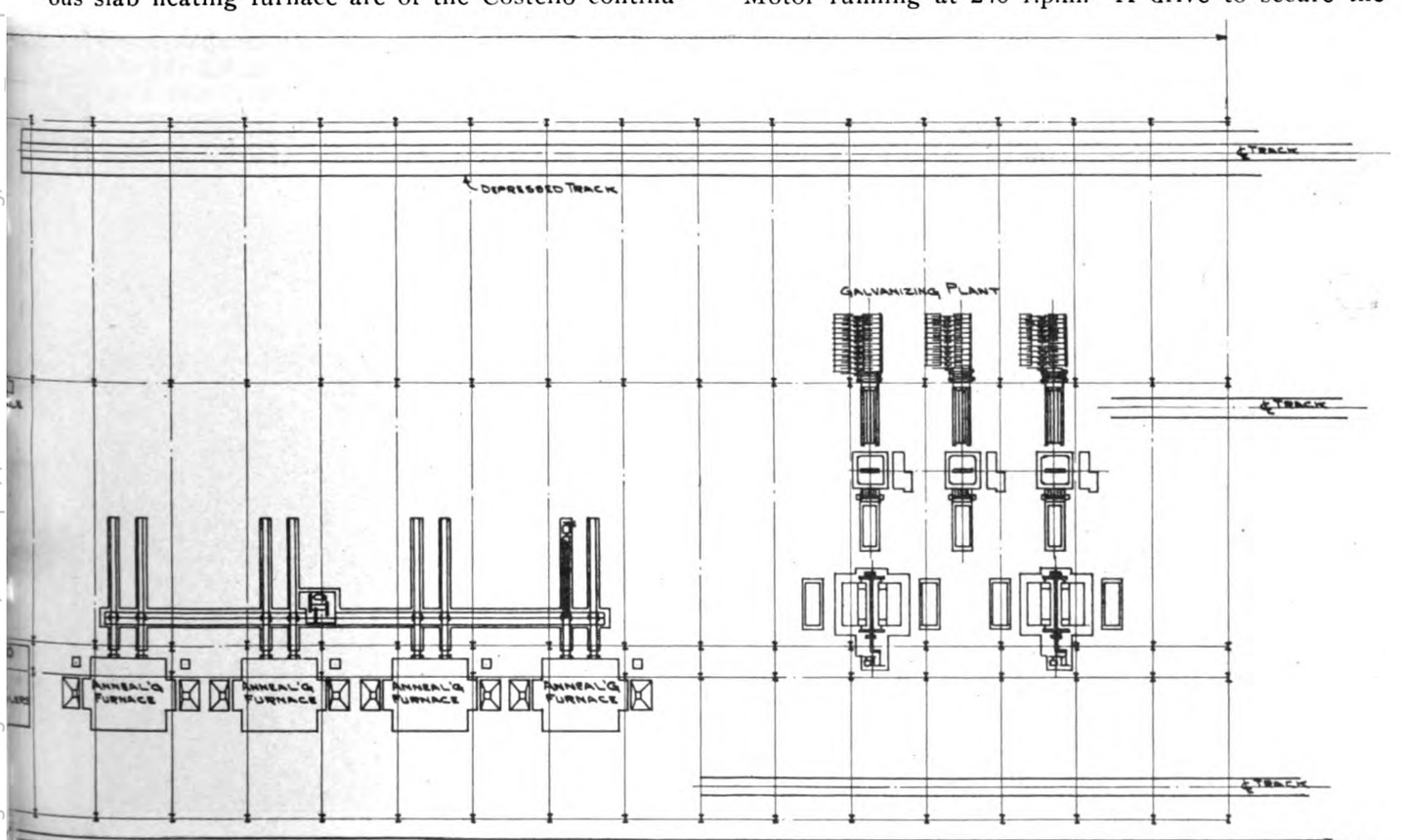


FIG. 3—*A view of roughing mills during construction, showing the method of designating each mill unit.*

labor for firing the furnaces. The continuous open annealer and portable annealer are fired with by-product coke oven gas.

Drive.

The mills are driven by a 2,000 h.p. Westinghouse Motor running at 240 r.p.m. A drive to secure the



... on left and furnaces shown on right simplifies internal transportation.

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necessary reduction in speed, was built by the United Engineering & Foundry Company. This drive consists of cut herringbone gears and give a speed reduction of eight to one. A complete Bowser Oiling System is installed to take care of the motor and drive.

Floors.

The floors or standings at the mills and furnaces are of the water cooled type, furnished by the National Roll & Foundry Company. Brick flooring is used to floor the bar building, furnace building, balance of mill building and the northern part of the warehouse. Wood block flooring is used in the shipping end of the warehouse.

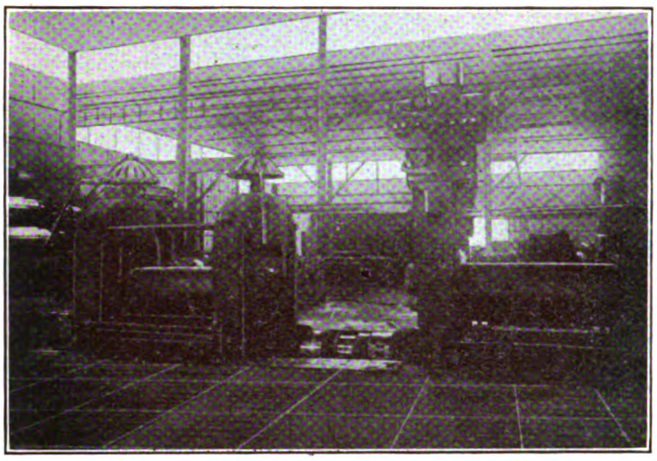

FIG. 4—*The jobbing mills at end of train—showing water cooled floor.*

Finishing.

The product of the jobbing mill is passed through the continuous Costello blue annealing furnace, then through the United Engineering & Foundry Company's Roller Leveller onto a conveyor built by the C. O. Bartlett & Snow Company. This conveyor delivers the sheets to a bed of castors directly in front of the 156 in. squaring shear. After the sheets are sheared they are ready for loading directly into cars, or for storage. This is easily accomplished as they are under the 10-ton warehouse crane.

The product of the sheet mills is handled with a minimum amount of effort. All sheets after being sheared, are carried by the crane to the cold rolls. The cold rolls automatically deposit the sheets on the annealing furnace bottoms. After the sheets have been covered they are lifted by the crane, onto the annealing furnace charger. This charger was built by the United Engineering & Foundry Company, and is electrically operated. After being annealed, the sheets

FIG. 6—*Difficulties often encountered in cramped roll storage facilities are entirely absent here. Every roll is immediately available. The heavy roll lathe is located directly back of and convenient to storage.*

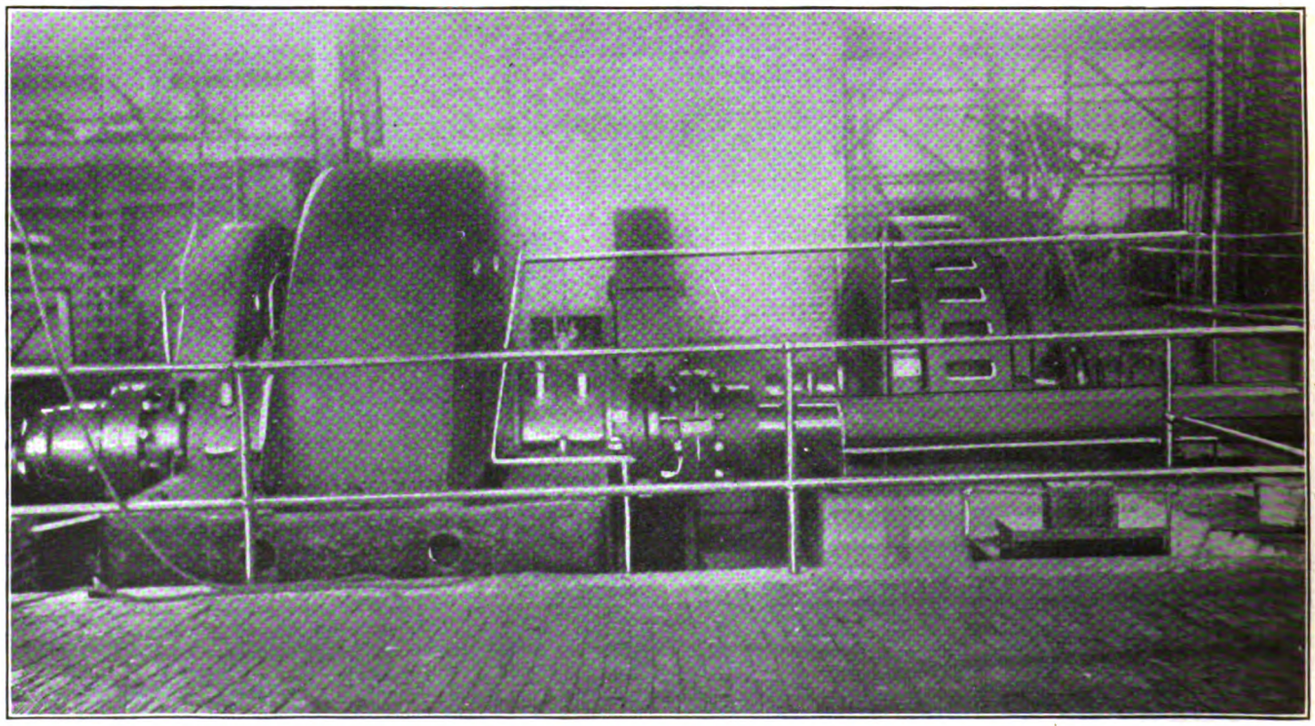

FIG. 5—*An excellent view of the mill drive with 2,000 h.p. Westinghouse motor. In the center background can be seen the control room wherein all electrical equipment is consolidated in a separate house. Ideal provisions have been made for ventilation and for quick repairs, through removable roof under the craneway.*

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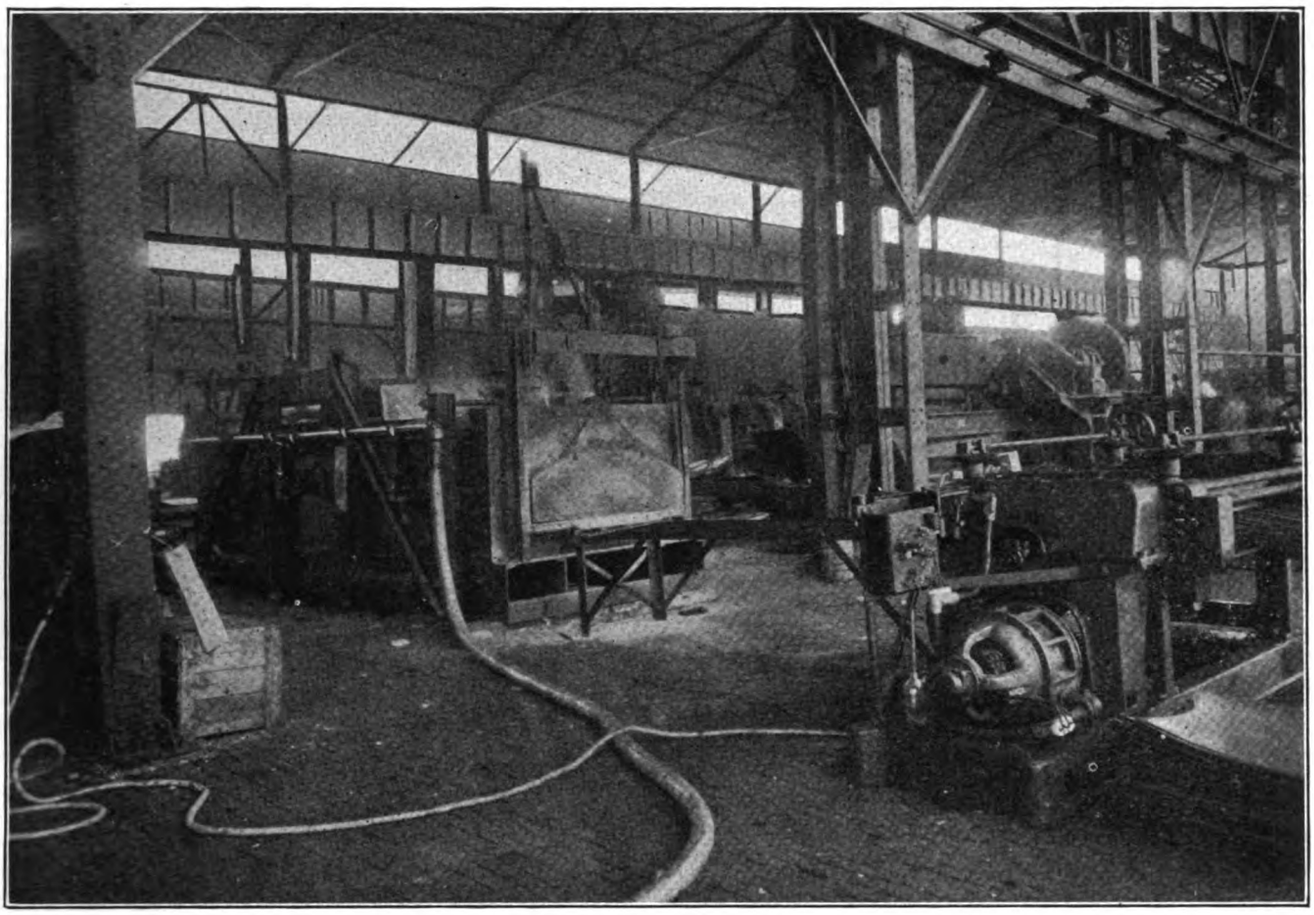

FIG. 9—*A feature of flexible operation. The portable blue annealing furnace. This furnace is fired with coke-oven gas from the by-product plant nearby, through the flexible hose connection shown in the center fore-ground.*

are either taken to the warehouse, or pickling department. The pickling machinery is of the oscillator type, motor driven, designed and built by the United Engineering & Foundry Company.

There are three galvanizing machines, complete with roller levellers, cooling wheels, conveyors, etc., furnished by the United Engineering & Foundry Company. By-product coke oven gas, piped direct from the St. Louis Coke & Iron Co's plant of 80 Roberts' ovens, is used for fuel. The burning equipment was furnished by the Surface Combustion Company. The galvanized sheets are deposited on bundling benches in the warehouse and directly under the 10-ton warehouse crane.

FIG. 7—*Shows the Costello charger in front of sheet and pair furnaces. Adequate coal hoppers taking coal from the crane delivery, supply the Jones underfeed stokers which equip all furnaces. Change to any other character of fuel may be quickly and easily made when necessary.*

Water Supply.

Water for use on the mills and in the Pickling Department is secured from deep wells. A connection to the city mains is used to furnish water to the boilers and for emergencies.

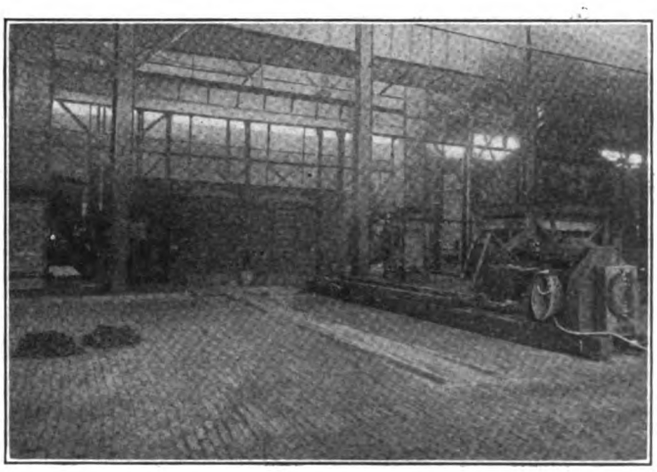

FIG. 8—*The annealing furnaces in the back-ground with a charger in the fore-ground.*

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Steam.

Two 205 hp. Heine Boilers are installed to furnish the steam for the pickling department and to operate the doublers—one boiler in use and one for a spare. The boilers are equipped with Illinois Chain Grate Stokers. A hopper over each stoker is filled from the coal bucket on the crane.

Electric Current.

The electric current for driving the mills and the a.c. auxiliary motors is purchased. The incoming

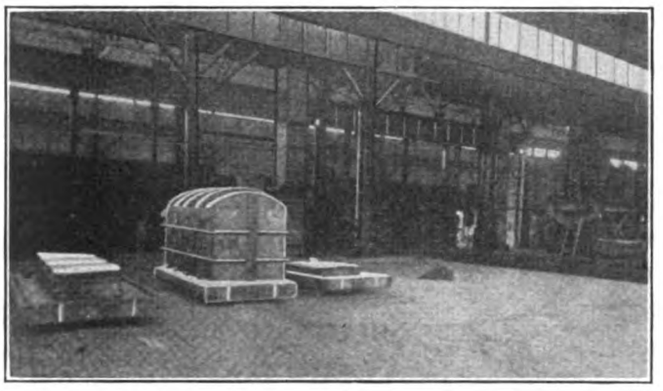

FIG. 9—*A glimpse of the annealing department with a single annealing box withdrawn in place on its cast iron base.*

line is 30,000 volts a.c. 60 cycle which is stepped down to 2,300 volts for the mill drive.

This current, in turn, is stepped down to 440 volts for the a.c. auxiliary motors. The lighting system is 110 volts a.c. The electric travelling crane and the variable speed motors in the mill operate on 220 volts d.c. The d.c. is furnished from a 500 kw. motor generator set.

Cranes.

The electric travelling cranes, four in number, one 10-ton 40 ft. 0 in. span, three motors, one 40-ton, with 10-ton auxiliary 75 ft. 0-in. span, four motors, one 20-ton, 75 ft. 0-in. span; three motors, and one 10-ton, 75 ft. 0 in. span three motors were furnished by the Alliance Machine Company. They are strictly mill type built cranes and represent the latest designs.

Auxiliary Electric Equipment.

All of the motors, with the exception of the drive and the crane motors, were furnished by the General

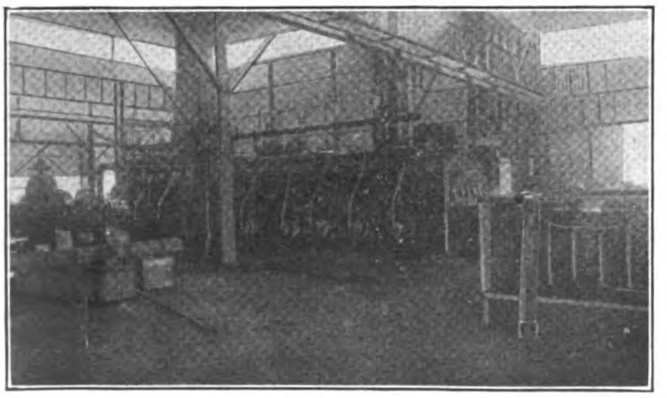

FIG. 10—*Tate-Jones continuous heating furnace, fired with by-product gas.*

Electric Company. They also furnished the switchboard, a.c. motor controls and transformers. The Westinghouse Electric & Manufacturing Company, furnished the drive and crane motors. All d.c. control was furnished by the E. C. & M. Co.

Coal.

The coal is received on a track on the western side of the bar building and is dumped, through drop bottom hoppers into a reinforced coal pit of about 250 tons capacity. A single line grab bucket on the bar mill crane picks up the coal from the pit and distributes it to the various furnaces.

Comforts.

Toilets and wash rooms are provided at convenient points.

Roll Lathes.

For turning the rolls, two 34-in. heavy duty type roll lathes with enclosed headstocks were furnished by the United Engineering & Foundry Company. Roll racks for storing all rolls are provided. The roll lathes are located in the mill building under the 40-ton crane, in order that the rolls can be handled with the least amount of effort.

MATERIALS AND PROCESSING RESEARCH

Probably no other branch of engineering work has added as much to engineering knowledge as that of the art of properly utilizing and processing of materials.

A new piston packing has been brought out by the use of a new impregnating material on a new leather.

Cadmium plating as a protective coating for nuts, bolts and threaded materials formerly sherardized and galvanized has been developed.

Considerable work has been done during the year for the purpose of developing methods of testing raw material so that qualities which heretofore have not been measurable can now be evaluated. One example is that of measuring the pliability of fish paper and mica wrappers and assigning definite values. Another is that of the viscocity test for use on shellac gums.

A new development has been completed, covering casting integrally, the end rings and bars of small motors. A new type of high rupturing capacity circuit breaker has been constructed and tested with success.

The Westinghouse engineers have made a thorough study of methods of super-voltage measurement and have introduced several improvements in the crest voltmeter system which has enabled them to increase the accuracy of measurement in testing. An air condenser has been developed the principle of which can be applied to any high voltage transformer with or without the standard condenser bushing. This, in connection with a rectifying system, can be used for accurate voltage indication without limit and avoids the discrepancies and variations due to using a solid dielectric condenser.

The research engineers have developed a new alloy steel for electrical work which represents a remarkable advance in the art of material for work requiring steel of high permeability which is relatively constant over a wide range. The core or iron losses with this new metal are remarkably low. Its first use was confined principally to radio equipment but its application may be extended to other lines of apparatus.

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THE SAFETY CRUSADE

A Real Safety Record

613 Transportation Workers Handle 131,616 Tons Molten Metal, With Consequent Works Production, Without Single Accident

November 4, 1923
Braddock, Pa.

Mr. J. B. Trusel, Superintendent
Safety and Welfare Department.

Dear Sir:—

The Transportation and General Labor Department of Edgar Thomson Works operated during the 31 days of October, 1923, without an injury of any kind being charged against its Safety record. This is a record of which every man in the department is proud, a record that may be equalled many times in the future, but can never be excelled in any one calendar month. The story of this wonderful accomplishment dates back to one of our regular Department Safety meetings held in the office of the Transportation and Labor Department, on December 31, 1921.

Mr. H. C. Roberts, Foreman of Locomotives, a member of the Department's Safety Committee, addressed the meeting on this particular occasion, and in the course of his address he said, "I would like to suggest, with the permission of our worthy chairman, that we take the month of January (1922) for a special drive on Safety in the Transportation and Labor Department and see just how near we can come to a 'no accident record' ".

Safety is most impressive when translated into actual applications.

The following letter portrays in most dramatic form the enthusiastic efforts which are daily being concentrated upon this problem. Nowhere more than in and about the labor and transportation departments of a great steel mill is untiring vigilance imperative. Many men of many minds must work intelligently and in co-operation; dangerous hazards must be recognized and anticipated. That a performance percentage of less than 100 is no longer acceptable is now a fact.

Previous to this time, operating the entire Department for a calender month without even a minor injury seemed an almost impossible task. We figured we were accomplishing wonders by going through a whole month without a lost time case. However, Mr. Roberts' suggestion was taken up and foremen were instructed to thoroughly inform the men in their charge that it was the great desire of the Department's Safety Committee to operate during the month of January without even a minor injury. We failed miserably in January, as we did in every succeeding month up to October, 1923. We finally realized our great ambition, and proved beyond any argument that no task, humanly possible of accomplishment, is impossible if men make up their minds to do it. The following table will show the result of our efforts to establish that record, "one calendar month without a scratch of any kind":

	1922			1923		
	L. T. Cases	D. T. Cases	Minor Cases	L. T. Cases	D. T. Cases	Minor Cases
January	2	0	4	0	0	4
February	0	0	9	1	0	6
March	0	0	8	0	0	20
April	1	0	9	0	0	18
May	0	0	13	0	0	19
June	0	0	21	0	0	33
July	0	0	16	0	0	31
August	0	0	10	0	0	20
September	0	0	2	0	0	10
October	0	0	2	0	0	0
November	2	0	8			
December	0	0	3			
Totals	5	0	105	1	0	161

We won the Inter Departmental Trophy for 1922 and retained first place in the race for the 1923 Trophy. Our minor injury record of June of this year threw a "scare" into us, with the result that an innovation in the way of having the groups, six in number, into which our department is divided, select from among their number one man to be candidate for a new hat which was donated by the Foremen's Association for the winner of a Safety contest between the groups, was inaugurated. The first of these contests was held in July, and was won by an engineer representing the Engineers and Foremen. The second contest was held in September, and was again won by the representative of the Enginemen The October contest resulted in a tie, all groups crossing the wire neck and neck.

The Foremen's Association, a voluntary organization of Foremen banded together and paying into a fund the sum of 25 cents per month for just such contests, willingly consented to award a new hat to each of the six groups' representatives. The award will be made at a regular department Safety meeting to be held in the Transportation office November 10th, at 12:30 P. M.

After 21 unsuccessful attempts to go one calendar month without an injury of any kind, the following "Safety Obligation" was sent out and signed by every man in the department:—

SAFETY OBLIGATION

I, ..., of my free will and without any mental reservation whatever, do accept the responsibility you now place on my shoulders. I realize fully the benefits that are mine and my family's when I am careful at my work. I resolve to keep my mind on my work during working hours. I will talk "Safety" as often as possible during the day.

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I will do everything in my power to help my department win the trophy.

I will be a real, live, active Safety Committeeman.

We Can and Will Win the Trophy

Check No.....

The story would not be complete if we did not give you an idea as to the amount of work performed by the employes of the department during this, our banner month. As the department is divided into three divisions, Transportation, General Labor and Tracks, I will give the records of each separately. The Transportation being the largest and employing the greatest number of men, I will begin with it. This end of the department worked throughout the month with an average working force of 322 men. During the month 1240 eight-hour crews operated engines for a total of 14,720 engine hours, and in this period handled 2,303 empty in-bound cars, 13,719 loaded in-bound cars, 3,309 loaded out-bound cars, and 12,761 empty out-bound cars, 4,813 cars with intra-mill moves, and they also handled a total of 131,616 tons of molten metal, or 3,761 ladles which were moved on an average of three times each, making a grand total of 11,283 moves on metal ladles. 6,199 ladles of cinder were handled by these men. These ladles, too, were moved on an average of three each, making a total of 18,597 moves. During this period they also handled 152,888 tons of works product, going through the whole month of October without any demurrage charges. Operating under conditions of a very hazardous nature, these 322 men worked throughout the whole month of October without an accident of any kind being charged against the department. These figures represent a complete report of work transacted by the Transportation end of the department for October, 1923.

The Track Department had an average daily working force of 95 men during the month. In addition to miscellaneous jobs on our tracks, narrow and broad gauge, throughout the plant, such as rearranging and relocating tracks east of the O. H. Department to suit the extension to the O. H. building, raising lining and surfacing bad sections in the several operating yards, grading, etc., the following material was handled and put into service in our tracks:

Material	Total
Rails, 100 P. S.	249
Splice bars, 100 P. S., pairs	292
Splice bars, 80 A	26
Steel cross ties, 5 ft. 6 in.	26
Steel cross ties, 8 ft. 0 in.	737
Steel cross ties, 11 ft. 0 in.	10
Steel switch sets, No. 6	7
Switch points	18
Frogs	8
Rails 80 A	16
Bridle Rods No. 1	18
W. O. ties, 8 ft. 6 in. to 15 ft. long	83
Economy switch stands	14
Spring ground throw stands	2
Parallel ground throw stands	2
Steel tie plates	1342
Gauge plates	7
Cast iron guards	44
Cast iron blocks	40
Cast iron clips	97
Triple breakable cranks	19
Auto foot catches	43
Turn buckles	20
Nut locks	12744
Bolts and nuts	12761
Kegs of railroad spikes	17
Steel tie clips	6253

101 switch plates and braces combined, and 4 100 P. S. 6 ft. switch points.

First row, left to right—F. F. Slick, Chairman, General Safety Committee; W. J. Dixon, Superintnedent Transportation and Labor Department, Russell Rose. Second row, left to right—Thomas Meehan, Stephen O'Malley, Peter Nee, R. I. Bair, Michael O'Toole, J. L. Corbett, A. J. Kramer, V. T. McCarthey. Third row, left to right—J. A. Lawler, Chairman, No. 3 Safety Committee, H. C. Roberts, E. A. Stonick, I. N. Yoder, J. K. Douglas, P. J. Holloran, J. J. Daly.

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In addition to the quantity of material put into use in our plant, the scrap removed from said tracks during the month amounted to 113 tons (estimated). We might add here, too, that the month of October has been the second consecutive month our Track Department has operated without even a minor injury, a record we certainly are proud of, when the many, many minor hazards that confront these men daily are considered.

The next largest division of the department is the General Labor. The Track Division is the smallest. The men of the General Labor Department are engaged in general labor and construction, unloading and loading cars, cleaning, etc. Their work too is of dangerous character and requires constant attention to avoid injury, as the majority of their work is hand labor. There were constantly on duty an average of 196 men per day in the General Labor Division throughout the month. It would be a very difficult matter to give an account of every job performed, but will give a few of the larger ones to give you an idea of what they really accomplished. During the month these men skulled 189 ladles of various descriptions. They handled 110 yard heats from the Open Hearth Department, and loaded a total of 5,414 boxes of charging box scrap for the O. H. Department, which averaged 2000 pounds per box, making a grand total of 4,834 tons 1,840 pounds. During the month these men were engaged on four different construction jobs, and time spent on each job was as follows:—Excavating at No. 1 Mill under hot beds tunneling sewers for No. 1 Mill to main sewer, digging foundation back of No. 3 Engine Room for hot saws to main sewer at No. 1 Mill, for which 2,844 hours were charged. The second job was digging foundations for new pier foundations for new O. H. furnaces, filling in around new O. H. work, excavating for new stock pit at O. H. Stock House, excavating for new water line at Nos. 15 and 16 O. H. Furnaces, for which 4,433 hours were charged. The third job was removing present building entrance to trainmen's building, excavating on east and west end of building, for new addition to this office, for which 838 hours were charged. The fourth construction job was excavating for new oil pump at the Splice Bar Mill, and digging sewer for same, for which 579 hours were charged. In all four construction jobs a total of 8,694 hours were recorded, and 24 cars of dirt were loaded and 34 cars of dirt and ashes were unloaded. (These cars are included in the report of cars loaded and unloaded for the month).

In addition to the foregoing, they performed the work shown in table on the succeeding page.

RECAPITULATION

Accidents during October	None
Average daily working force	613
Empty inbound cars	2,303
Loaded inbound cars	13,719
Empty outbound cars	12,761
Loaded outbound cars	3,309
Intra-mill moves on cars	4,913
Molten metal handled—ladles 3,761; tons	131,616
Moves made on molten metal ladles	11,283
Ladles of cinder handled	6,199
Moves made on cinder ladles	18,597
Works production handled, tons	132,888
Construction jobs engaged in	4
Hours recorded on construction jobs	6,694
Ladles skulled	189
Open hearth yard heats handled	110
Charging box scrap loaded, boxes	5,415
Tonnage of C. B. scrap loaded, tons	4,834
Total miscellaneous items loaded, cars	1,248
Total miscellaneous items unloaded, cars	905
Scrap transferred from barges to cars, tons	5,750
Scale transferred from barges to cars, tons	600
New material handled by track men, pieces	35,000
Demurrage charges for October	None

Hoping, the balance of the year, to lead the department through the safest year in its history, and by so doing to help establish a similar record for the Edgar Thomson Plant, I remain,

Respectfully yours,

(Signed) W. J. Dixon, Superintendent
Transportation and General Labor Dept.

METALLOIDS IN OPEN-HEARTH

(Continued from Page 50)

Heat Generated

Oxidation of carbon, weight = 2667 lb.
Heat of formation of CO from C per lb. = 4374 Btu.
Heat generated = $4374 \times 2667 = 11.67 \times 10_6$
Oxidation of manganese, weight = 604 lb.
Heat of formation of MnO = 2984 Btu.
Heat generated = $2,984 \times 604 = 1.80 \times 10_6$
Oxidation of silicon, weight = 488 lb.
Heat of formation of SiO_2 = 11,683 Btu.
Heat generated = $11,693 \times 488 = 5.71 \times 10_6$
Oxidation of phosphorus, weight = 129 lb.
Heat of formation of P_2O_5 = 10,825 Btu.
Heat generated = $10,825 \times 129 = 1.40 \times 10_6$
Heat of formation of slag weight = 11,423 lb.
Heat of formation of slag = 104 Btu.
Heat generation $11,423 \times 104 = 1.19 \times 10_6$
Total heat generated = $21.77 \times 10_6$ Btu.

Authorities for Constants Used

THERMOCHEMICAL CHANGES

Iron oxide reduction—Richards
Decomposition of limestone—U. S. Bureau of Standards.
Oxidation of C, Mn, Si, P—Richards, LeChatelier, Berthelot, Thomson
Formation of slag, calculated using Richards' values

THERMOPHYSICAL CHANGES

Specific heat, pig iron—0.1665—Oberhoffer
Specific heat, soft steel—0.16—Meuther
Latent heat of fusion, pig iron—Hutter
Latent heat of fusion, steel—average value—Jetner, Richards, Brisker
Heat in molten slag—Springorum

Thermal Balance Sheet

HEAT ABSORBED

Red. of oxides of Fe	=	16.42
Absorp. moist. of ore	=	2.34
Decomp. of limestone	=	5.08
Absorp. moist. of limestone	=	0.32
Recomp. of dolomite	=	0.67
Heat in molten slag	=	12.18
Heat added to mixer metal	=	7.88
Heat added to scrap	=	19.82

HEAT GENERATED

Oxidation of C	$= 11.67 \times 10_6$
Oxidation of Mn	$= 1.80 \times 10_6$
Oxidation of Si	$= 5.71 \times 10_6$
Oxidation of Si	$= 5.71 \times 10_6$
Oxidation of P	$= 1.40 \times 10_6$
Heat form. slag	$= 1.19 \times 10_6$
Balance heat to be supplied by combustion of gases in furnace	$= 42.94 \times 10_6$
Total Btu.	$= 64.71 \times 10_6$

THERMAL EFFICIENCY OF BATH

Thermal efficiency of furnace = 17.3 per cent.
Btu. in gas per pound of coal = 10,625

$$\text{Total Btu. to be supplied in producer gas} = \frac{42.94 \times 10_6}{0.173} =$$

$248.21 \times 10_6$ Btu.
Total coal burned = 23,361 lb.

(To be continued)

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By-Product Coke and Gas Oven Industry in 1923

By C. J. RAMSBURG*

THE outstanding event in the by-product coke oven industry in 1923 was undoubtedly the completion and successful operation of the plant of 37 Becker type ovens at the Weirton Steel Company, Weirton, W. Va. This plant was put into operation in July and has borne out in practice all of the earlier predictions of the designers. It has operated continuously on a coking time of less than 11 hours and 30 minutes, carbonizing approximately 1,060 tons of coal per day or 29 tons per oven day, which is probably a world's record for coal carbonization per oven. The yields have been approximately as follows:

Total coke	795 net tons
Gas, debenzolized.	11,400 cu. ft. of 555 Btu. per net ton of coal
Tar	13.0 gallons per net ton of coal
Am. sulphate	24.0 pounds per net ton of coal
Light oil	4.3 gallons per net ton of coal

The plant has operated entirely on straight high volatile coals from the Pittsburgh District, no Pocahontas or other low volatile coals having been used. The coke produced has been used in the blast furnace of the Weirton Steel Company with very excellent results, the furnace having averaged as high as 610 tons of iron per day on straight lake ores. This would seem to show very conclusively that when using straight high volatile coal from the Pittsburgh District there is no question but that a satisfactory blast furnace coke can be made in the Becker type oven. In view of the high freight rate on Pocahontas and other low volatile coals, this should result in a decided savings in the cost of coke, and, consequently, in the cost of producing iron. It is also pertinent to state here that the coke consumption per ton of iron produced has been lower when using coke made in these ovens than when using beehive coke.

At the present time there are under construction in the United States and Canada a total of 701 ovens having a combined carbonizing capacity of 6,015,950 net tons of coal per annum, all of which are of the Becker type designed and being built by the Koppers Company. These ovens are located as follows:

BY-PRODUCT COKE OVEN PLANTS

Carnegie Steel Company, Clairton, Pa.....	366
Columbia Steel Company, Salt Lake City, Utah.....	33
Republic Iron & Steel Company, Youngstown, Ohio....	61
Bethlehem Steel Company (Lackawanna Plant), Buffalo, N. Y.	114
Trumbull Cliffs Furnace Company, Warren, Ohio.....	27
Diamond Alkali Company, Alkali, Ohio.....	23

BY-PRODUCT GAS OVEN PLANTS

Consumers Power Company, Zilwaukee, Mich.....	19
Winnipeg Electric Railways Company, Winnipeg, Can..	17
Utica Gas & Electric Company, Utica, N. Y.....	21

In addition to the three gas plants named above, there was built, during 1913, a plant of 11 Becker type gas ovens for the Battle Creek Gas Company, Battle Creek, Mich., and this plant is about to go into operation as this is written. All of the gas oven plants above mentioned, including Battle Creek, are of the same general design as the coke ovens, but are approximately only one-half the size of the standard coke ovens, having capacities of from 5.5 to 6.8 tons of coal per charge. The size of the oven is determined entirely by the local conditions existing where the plant is built and the gas-make desired, it being perfectly practicable to make the oven smaller or larger as desired. The above mentioned plants range in capacities from 150 tons of coal per day at Battle Creek to 285 tons of coal per day at Utica. All of these ovens will be underfired with producer gas and the capacities given are based on a coking time of

MR. C. J. RAMSBURG

12 hours, although it is, of course, possible to increase this coking time as desired and to reduce it to as low as 10 hours. The ovens can also be heated with blue water gas or oven gas. When oven gas is used, approximately 65 per cent of the total gas produced is available for domestic distribution, as compared with 100 per cent when using producer gas or blue water gas for underfiring. Provision is also made for steaming of the ovens to recover additional gas. All of these features combine to give to these plants the great flexibility so essential in domestic gas manufacture.

It is very gratifying to see how quickly the gas industry has recognized the great advantages of car-

*Vice President, The Koppers Company.

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bonization in bulk as exemplified in these plants as there is no question but that this method of carbonization is far more efficient and practicable than ordinary retort practice.

It is also interesting to note that both in England and in France there has been widespread interest shown in American coke oven practice. It is a well known fact that both on the continent and in England there has been a tendency to adhere to old design and obsolete methods of operation which, no doubt, has been due to the fact that during the war there was no time for research or development work to be done. In the past few years a number of men prominent in coke oven design and operation on the other side have visited this country, all of whom were greatly impressed by the progress made here in by-product coke oven design and operation, and under the stimulus of the information secured there is a rapidly growing conviction that steps must be taken to bring their design and operation to a more efficient basis. This movement has spread to such an extent in England and in France that the Woodall-Duckham-Jones Company of England and the Societe Anonyme de Carbonization et de Distillation des Combustibles in France, have arranged with the Koppers Company to handle the sale and building of the Becker type oven in these countries. A battery of Becker ovens is now under construction in France. The silica brick shapes are being shipped from this country, but there is reason to believe that within a short time English and French refractory companies will be in position to furnish all the brick required in the building of these ovens. All indications point to the building of a number of American ovens in these two countries and the adoption of American methods of operation.

As in previous years, the production of by-product coke as compared to beehive coke has continued to increase, approximately 85 per cent of the total coke produced in the United States having been made in by-product ovens. The indications are that it will be only a few years before all of the coke used in this country in normal times will be produced in by-product ovens and that the beehive oven will only be used in boom times when coke is scarce and prices are high. One factor which may retard this desired result, however, is the situation which has developed in connection with the cost of carrying coal to the by-product coke plant and shipment of the coke produced. It requires approximately 1.4 tons of coal to produce a ton of coke and the freight on this coal from the mine to the by-product plant, plus the

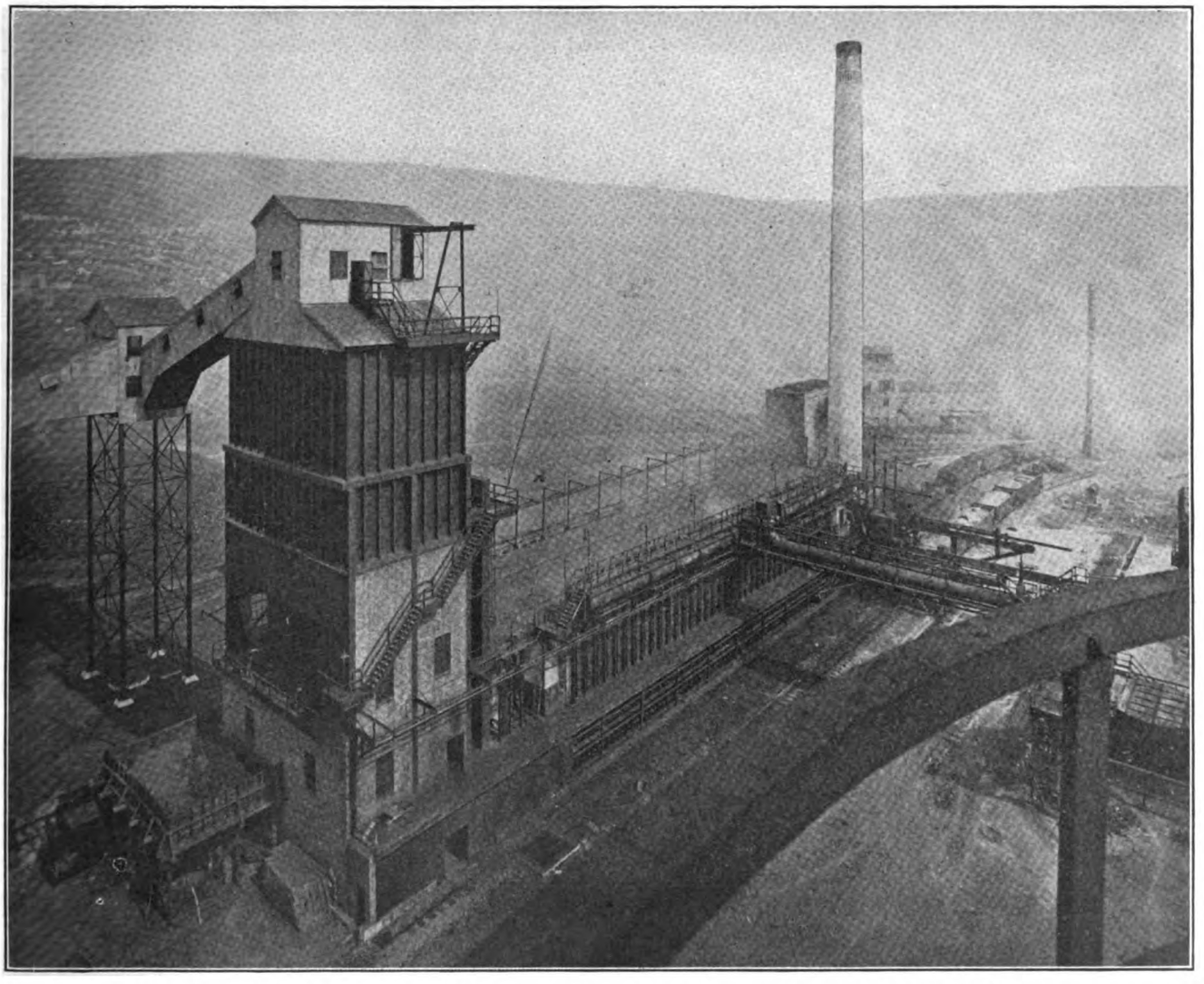

FIG. 1—*An excellent birdseye view of the new battery of 37 Becker type ovens at Weirton Steel Company.*

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freight on the resultant ton of coke from the by-product coke plant to the point of consumption is in most cases more than the freight rate on beehive coke from the ovens to the point of consumption. This is due to the fact that beehive ovens are generally located at the mouth of the coal mine and this permits shipment of only the coke to the point of consumption. Present freight rates are such that beehive coke has the advantage in most cases. While it is true that most of the by-product ovens are located at the iron and steel plants where most of the coke is consumed, there is generally a certain percentage of smaller sized coke unsuitable for use in the blast furnace which has to be disposed of as domestic fuel or otherwise, and this inequality in freight rates creates a situation which works a hardship on the by-product coke oven operator. This is especially true in the operation of by-product coke plants and not intended primarily to furnish coke for furnace operation, but built as merchant plants, depending on territories within reasonable limits for a coke market.

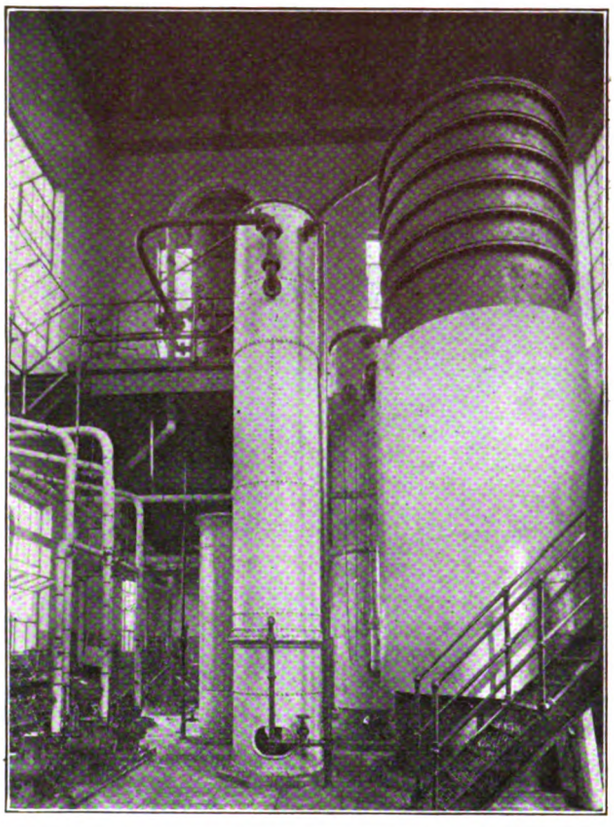

FIG. 2—*Interior of benzol motor fuel plant, Weirton.*

This situation has been called to the attention of the Interstate Commerce Commission, however, and there is hope that a solution of this difficulty will be found, as it is almost generally recognized now that to produce coke in beehive ovens is a practice contrary to all of the dictates of present day knowledge and inimical to the best interests of the country.

American coke oven operators have reason to congratulate themselves on the great strides which have been made in coke manufacture, but there is still a great deal of development and research work to be done. It is idle to think that we have reached the millennium in this industry despite the fact that it now takes us but 11 hours to accomplish what formerly required from 48 to 72 hours. One very gratifying feature of the construction work in the past year has been the fact that all of the ovens contracted for are of the combination type which can be operated either with producer gas, blast furnace gas, coke oven gas or blue water gas.

The use of coke oven gas and tar in the open hearth plant is a matter which should be given more study. While considerable progress has been made in this connection it would be well for iron and steel companies operating by-product coke plants to consider the advisability of a partial distillation of their tar before burning it in the open hearth plant, recovering the light oils, tar acids and some of the heavier oils such as creosote oil and burning only the residual tar in the open hearth. There is a great demand for these tar oils and the revenue derived from their sale would help to reduce the cost of steel.

The indications are, however, that all concerned are exerting every effort to solve the many problems confronting the by-product coke oven industry and that the research and the development work which has brought the industry to its present high state of efficiency will continue.

A LIFTING MAGNET THAT WON OUT

For many years the Ferro Machine & Foundry Company, of Cleveland, who melt at least a car of iron each day, have employed a locomotive crane with magnet to do the unloading and other material handling work but finally the magnet which was of an old design, no longer made, gave out completely and the maker advised them to buy a new standard magnet of modern design.

The electrician, loath to give up an old friend, made plans to rewind the coil and rebuild the magnet but was prevailed upon to listen to the magnet salesman and his own estimate of the cost was $1,000.00 and of the time, which included the making of a pattern and buying a manganese steel casting ground to size also buying the copper and winding the coil, was two months.

The yard boss was then called in and stated that it would cost them twenty dollars per day to do the magnet's regular work by manual labor which meant another $1,000.00 for the 50 working days.

Rebuilding the old magnet would thus cost them $2,000.00 with no one to guarantee its useful life whereas a new one would cost less than $1,500.00 and be covered by an absolute guarantee for one year and be of moder ndesign with greater lifting capacity and a useful life expectation of 15 to 20 years.

The next day they bought the magnet shown on their crane in cut herewith.

This is the exact story of a typical case as related by F. W. Jessop of the Ohio Electric & Controller Company of Cleveland. Magnet appropriations are hard to get but once obtained the operating department wants the magnet the next day.

The Cleveland-Cliff Iron Company announces the removal of its offices from the Kirby Building to the fourteenth floor of the Union Trust Building, Cleveland.

E. Keller Company, Williamsport, Pa., announce the appointment of Mr. C. C. Loder as sales manager, Pittsburgh territory, with headquarters Room 609 Chamber of Commerce Building, Pittsburgh, Pa.

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The POWER PLANT

Boiler Efficiency

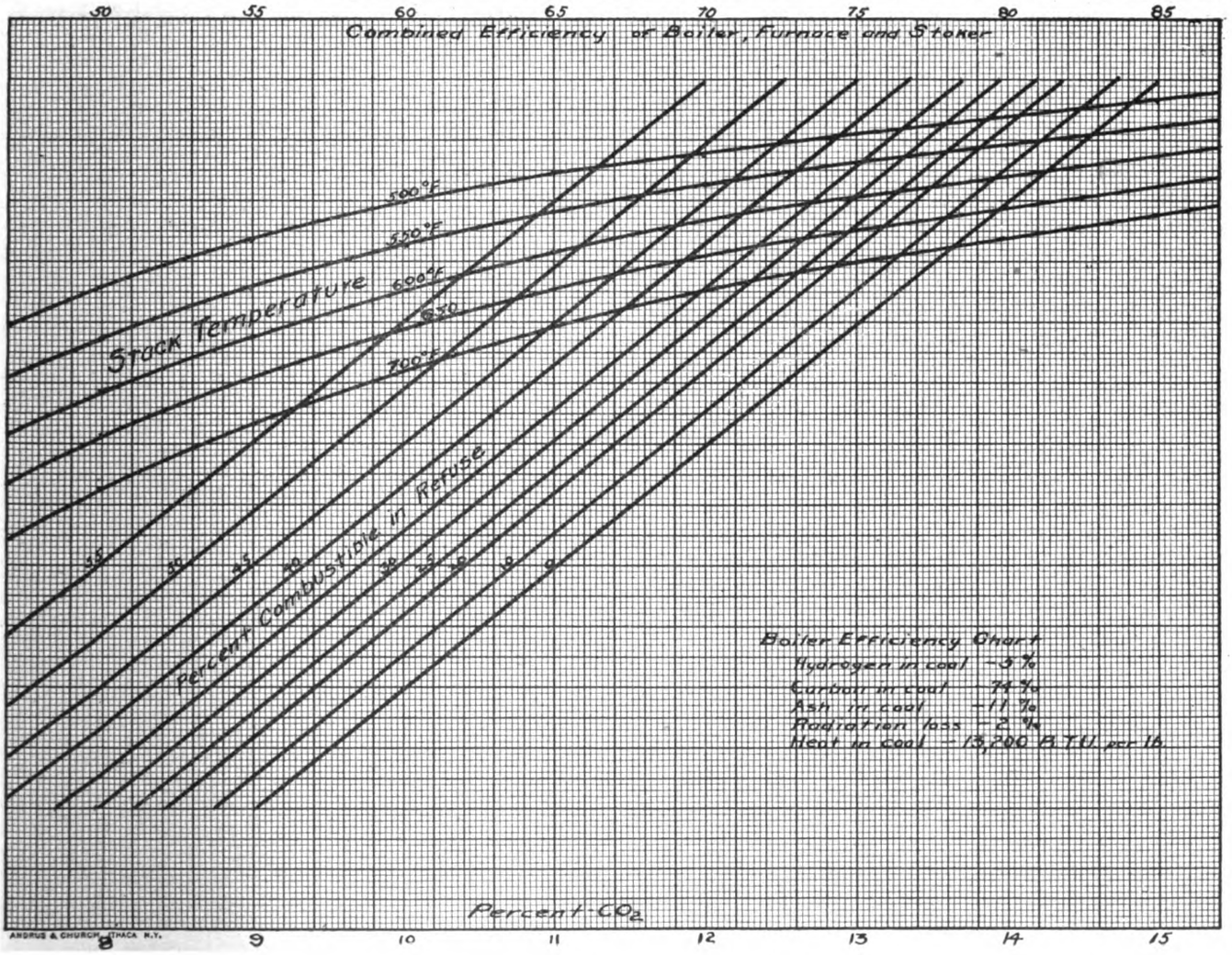
The Relation of CO_2 to Ash Pit Losses Must Be Carefully Observed

By CHARLES E. COLBURN*

THERE are at the present time few large boiler plants in which the importance of maintaining low values of excess air is not appreciated. Although there are a vast number of plants operating with large amounts of excess air, there are on the other hand numbers of cases where the CO_2 is maintained higher than is required to make the sum of the boiler losses a minimum. This kind of operation usually results where bonuses based upon the CO_2 percentage are paid. With some of the most commonly used types of stokers it is usually very easy to maintain high CO_2 values if no consideration is given to the other losses in the boiler. It has been found that even with good stoker fired furnaces in which the ash pit losses can be kept low when the CO_2 percentage is high, the firemen will secure high CO_2 by allowing the ash pit losses to become large. Several of the large power plants have tried out bonus systems based upon the CO_2 percentage and have abandoned them when it was found that increase in ash pit losses was greater than the decreased stack losses resulting from the higher CO_2.

*West Penn Power Company, Springdale, Pa.

Operators having this experience should not come



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to the conclusion, as is done in some cases, that it does not pay to maintain the higher CO_2. They should realize that the excess air should be reduced by keeping the fuel bed more even, especially at that part of the grate where the fuel is near the point where it is discharged from the furnace and not by discharging the ash with so high a percentage of combustible as to insure there being some combustible in the ash passing over those parts of the grate surface that would otherwise have been burned out. Although every stoker has its limitations, that is, even with the best of firing there will be a value of CO_2 which if exceeded will result in reduced efficiency, this limiting value is usually higher than the operators realize.

For any given stoker or furnace the value of CO_2 that it will be desirable to carry will depend upon the ability of the stoker operators. With poor operators it will usually not be desirable to keep the excess air so low as with good firemen because the better firemen will obtain the higher CO_2 without greatly increasing the combustible in the refuse. To obtain maximum efficiency in a plant a great deal of study must be given the boiler losses. Of course, great improvements can be made by training the firemen to carry more even fires, but with any given degree of firing ability, the combination of conditons that give the best results should be determined by studying the ash pit and stack losses obtained with various loads and CO_2 percentages.

Manufacturers of different types of stokers usually furnish curves showing the rate of operation that will give highest efficiency. Due to variation in the boilers and furnaces that the stokers are used with, the point of maximum efficiency is usually found to occur at some different rating than that shown on the manufacturers' curves. Sometimes great improvements can be made by doing nothing more than changing the number of boilers used to carry a given load so as to operate with a different average boiler rating.

Fig. 1 shows a chart that can be used to determine the boiler efficiency from the boiler losses. This chart should be very useful in studying the effect of the different operating methods on the losses. The boiler efficiency can be very actually determined by the use of this chart when the coal used is of the kind for which the curves were designed. With other kinds of coal, although this particular curve will not give absolutely correct results, they will be relatively correct. That is, the operating conditions which result in the highest efficiency as shown by this chart will be within the limits of experimental error, those that will give the highest efficiency. The slight inaccuracy that results from the assumptions that are made in making the chart shown in Fig. 1 are more than compensated for by the saving in time that will result from its use.

New Sectional Accumulator Heater

There has now been perfected by Messrs. Daniel Adamson and Company, Ltd., of Dukinfield, near Manchester, a new sectional modification of their well-known "Adamson-Cruse" accumulator superheater.

In designing a superheater, the best principle is to split up the steam into as large a number of thin layers or columns as possible, so as to increase the efficiency of the heat transmission. If, however, very small-bore steel tubes were used in a superheater to attain this object, they would be liable to warp and burn out unless excessively thick tubes were used, which would mean, of course, an impossible first cost, whilst at the same time any grit and dirt would soon cause stoppages. Consequently, in most superheaters a rough compromise is effected, and, say, 1 in. to 1½ in. tubes are employed—that is, moderate strength and medium heat transfer.

In the Adamson superheaters, however, a different principle is adopted, especially large mild-steel seamless tubes being used, 4-in. diameter and ¼-in. thick, in the form of the usual loops suspended in the hot exit boiler gases from the boiler, and attached to headers. Inside these 4-in. tubes, in the straight vertical portions, is placed an internal gilled cast-iron core with a hollow center. The steam, in passing down the steel tube, is split up into five layers—one in the center of the core and four between the middle of the core and the outside of the steel superheater tube, the core having four projecting gills or arms. As a consequence the heating of the steam is extremely effective, each of the four outer divisions of the steam being heated by the wall of the superheater tube suspended in the flames and hot gases, whilst the steam in the fifth and inner central division is heated from the cast-iron core, which is touching the outer steel tube at a number of points. The design is so arranged that the steam enters the first half of the top header of the superheater, passes down the vertical portion of the first loop, is split up into five portions, then reunites and mixes in the bottom bend, passes up the second vertical portion, is divided as before, then into the second portion of the header and down a second loop, and so on. That is to say, in its progress through the superheater the steam is four times in succession split up into five parts and reunited again, giving both a highly efficient heat transfer and a very even superheat, because of the thorough mixing of the different layers. Further, the central cast-iron core stores up a large amount of heat, acting as an accumulator in this respect, so as largely to equalize the temperature variations which are one of the inherent defects of superheating, due to the difficulty of maintaining an even temperature of superheat with a varying flow of steam, which does not correspond with the alteration in the amount of heat in the exit boiler gases.

The new sectional modification that has now been put on the market retains these essential features, but the two top headers are made of 6-in. cold-drawn mild-steel piping, and contain underneath a series of 4-in. nipples, welded on. The superheater tubes, in the form of the usual loop, are attached to these nipples by means of a long, heavy external nut, engaging in a screw-thread on the outside of the superheater tubes and the nipples, whilst a joint is made by means of a small corrugated copper ring. On screwing up, the joint is perfectly steam-tight and protected from the flames and hot gases, since the threads are totally enclosed in the protecting nut.

The design is such that any tube can be separately withdrawn, replaced, or blanked off, or additional tubes installed in a few minutes; and a further important advantage also of this sectional design is that the various parts are easily handled, shipped, and transported, whilst the superheater can be put together actually in the downtake.—Mechanical World.

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Unusual Blast Furnace Boiler Plant

The Most Recent Adaptation of Blast Furnace Gas Firing in Combination with Pulverized Coal

By GEORGE G. CRAWFORD*

AN installation of steam boilers having a total rated capacity of 5,000 hp. has recently been placed in operation by the Tennessee Coal, Iron & Railroad Company at its Ensley Works, Birmingham, Ala., as an addition to its blast furnace boiler plant, primarily for the purpose of meeting the peak load requirements and maintaining a constant and uniform supply of steam to the various power plants and mills. These boilers form an additional unit to an existing boiler plant of 24,000 bhp. rated capacity, using surplus gas from six blast furnaces.

This installation consists of a battery of six 834 hp. boilers, built for 250 lb. steam pressure, and equipped with superheaters designed for 200 deg. superheat. Blast furnace gas is used as a fuel when available and powdered coal is used as an additional fuel when gas is not available in sufficient quantities to meet the steam demands.

*President, Tennessee Coal, Iron & Railroad Company, Birmingham, Ala.

The features of this installation are the methods employed of automatically controlling a relative mixture of gas and air for the gas burners, and for supplying powdered coal as a supplementary fuel as required for maintaining a uniform pressure in the main steam line. This method helps to overcome a problem usually experienced in blast furnace boiler plants resulting from a fluctuating, and frequently insufficient gas supply, aggravated by sudden and large steam demands. This condition was previously partially overcome by hand-firing coal on a number of the gas fired boilers provided with plain grates for this purpose. This practice was not only inefficient but was very costly to operate, requiring a considerable force of laborers for firing and handling coal and ashes.

Coal Pulverizing Plant.

The coal pulverizing plant is located about 300 ft. northwest of the boiler plant, and alongside the elevated approach tracks to the furnace stock bins. This loca-

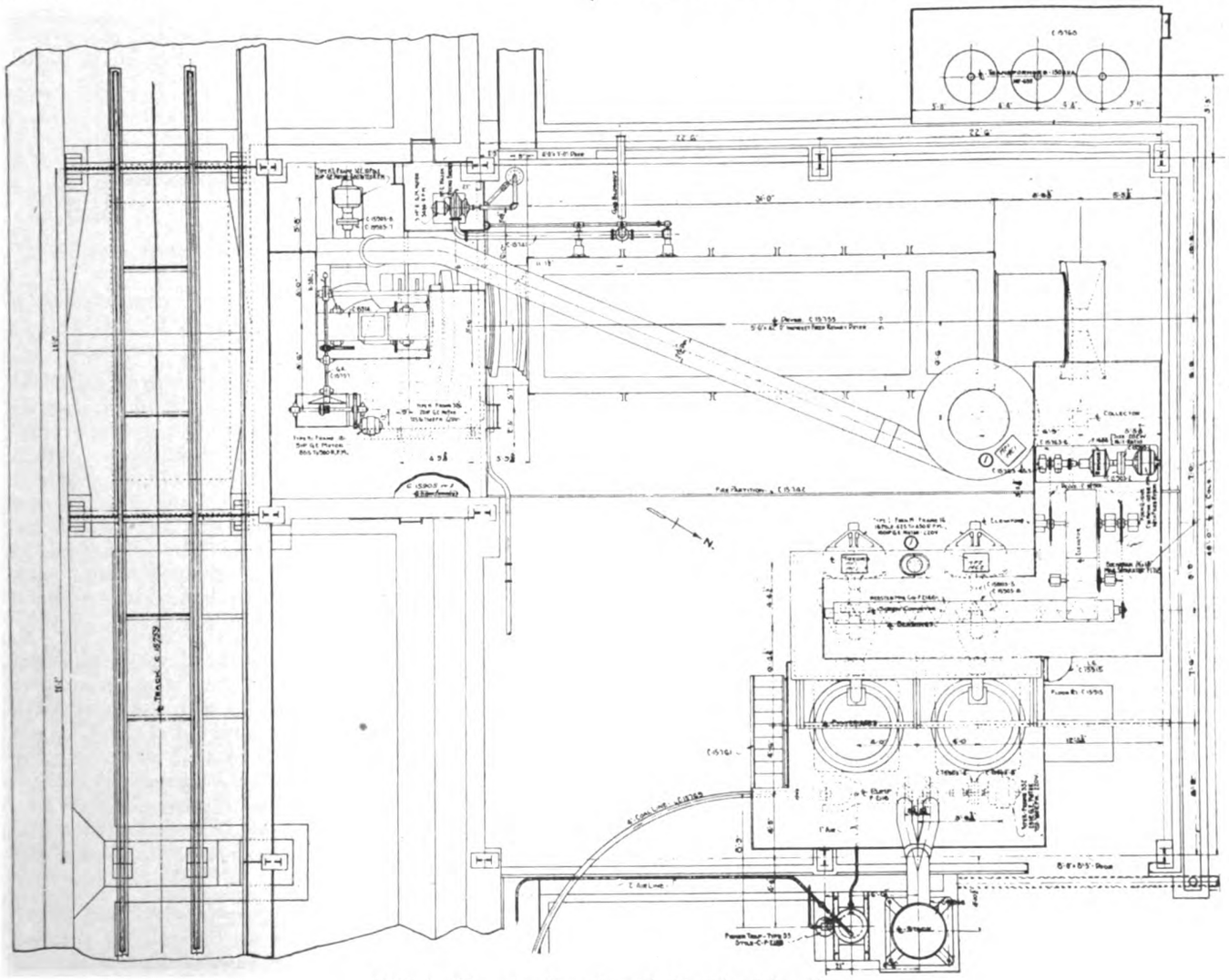

FIG. 1—*Shows a plan view of the pulverizing plant.*

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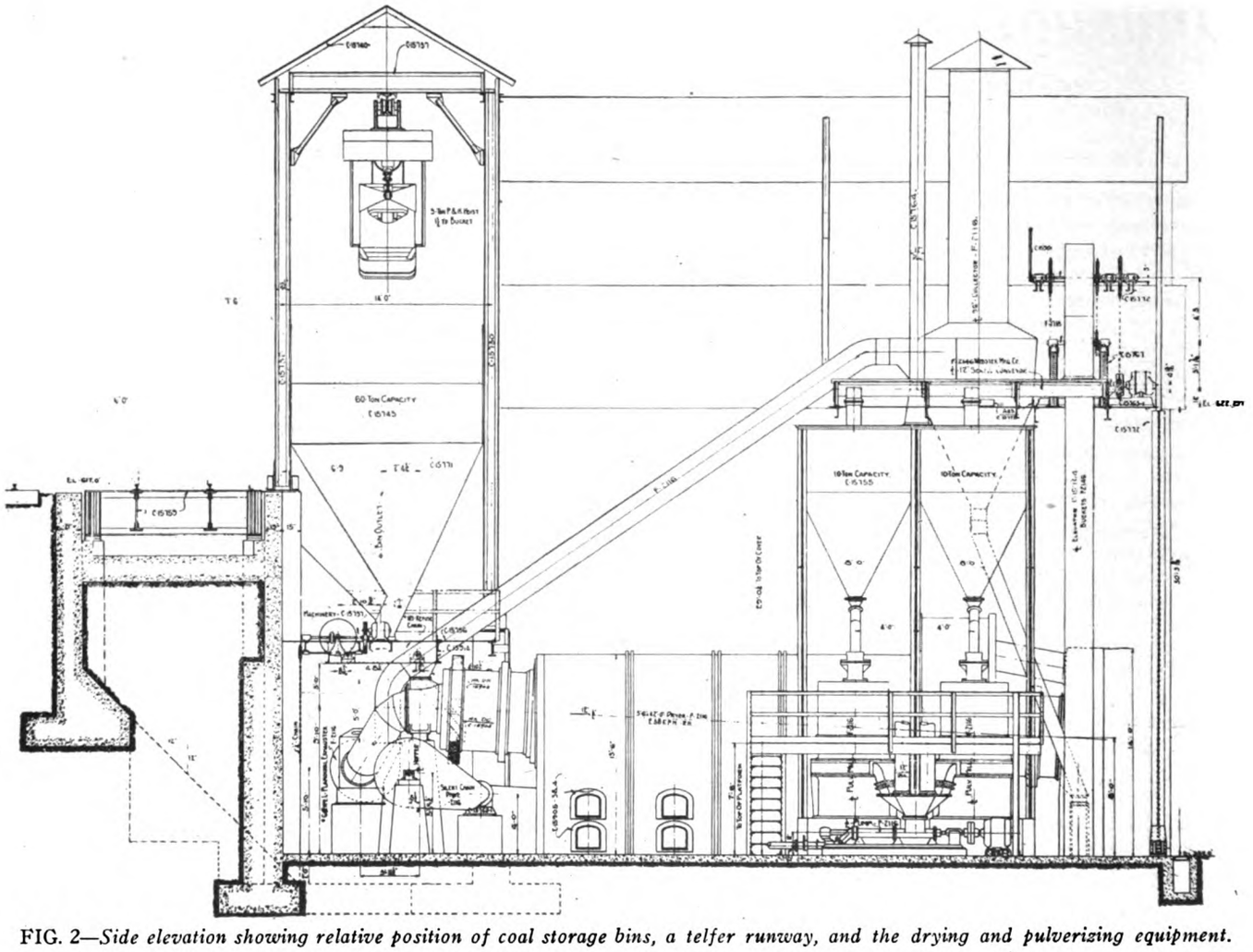

FIG. 2—*Side elevation showing relative position of coal storage bins, a telfer runway, and the drying and pulverizing equipment.*

tion was decided upon on account of the ideal condition afforded for dumping and storing the coal supply and of the isolated position which reduces the fire hazard.

The coal is either boiler coal, which is a middle product from coal washers preparing coal for by-product coke ovens and carrying from 20 per cent to 25 per cent ash and up to 10 per cent moisture, or high ash coal screenings, either of which will average between 11,000 and 12,000 Btu. per pound on a dry basis. All of this coal is crushed to under one inch size before being washed. Coal is delivered to the pulverizing plant on a high level track over concrete trestle bins with a storage capacity of about 1,500 tons. The bottom of the bins has a slope of 45 deg., causing the coal to shift to one side of the track and under a telpher runway equipped with a 3-ton hoist with a 1½ cu. yd. grab bucket. From here the coal is transferred to a 60-ton capacity steel bin located over the charging end of a rotary drier.

This bin has a hopper bottom with a spout to a feeder box in which is operated a drag chain to feed the coal to a chute discharging into the drier. The feeding device is driven by a 5 hp. motor through a variable speed friction drive which can be adjusted from the ground floor.

The coal drier is a 5′ 6″ by 42′ indirect fired drier with a rated capacity of 12 tons per hour, reducing moisture from 10 per cent to about 1½ per cent. The drier is fired with by-product coke oven gas and is equipped with grates for burning coal in emergency. Draft is furnished by a 60″ exhaust fan direct connected to a 15 hp. motor, and discharging into an 8 ft. cyclone collector suported overhead between the roof trusses.

The collected coal dust recovered from the draft exhaust is discharged periodically by an automatic damper in a spout leading from the collector to the drier discharge chute. The dried coal is lifted by a vertical bucket elevator and discharge over a 24x18 in. magnetic separator for removing tramp iron and then passes through 12 in. screw conveyor into either of two 10-ton capacity bins located over the pulverizers. The coal is then spouted to two 46 in. screen type pulverizers, each with a rated capacity of 5 tons per hour and driven by 100 hp. motors through a bevel gear reduction.

A fire wall partition separates the drying equipment from the pulverizing equipment to reduce the possibility of a dust explosion. The plant is also equipped with a vacuum cleaning system, consisting of a 3 hp. motor driven turbine with a suction pipe system with 2 in. plug connections for detachable vacuum cleaners located in various places in the plant. Coal dust is collected into a 30 in. primary collector and an 18 in. secondary collector located over the pulverizer bins to where the recovered dust is returned.

Fig. 1 shows a plan of the coal pulverizing plant. Fig. 2 is a side elevation showing the relative position of the coal storage bins, a telpher runway, and drying and pulverizing equipment.

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Transport System.

The powdered coal passes from the two pulverizers into a 6 in. screw type pulverized material pump directly driven by a 25 hp. motor. This pump delivers the material through a 4 in. transport pipe over a maximum distance of about 650 ft. to bins suspended over each boiler.

To facilitate the flow of the powdered coal through the transport line, compressed air at about 30 lbs. pressure is injected into the coal through small nozzles in the pump in a sufficient quantity to cause the coal to remain in an "expanded" condition until it is delivered into the boiler coal bins where the air escapes through vent pipes as the coal assumes a settled condition.

A small compressed air line is placed alongside the transport line with ½ in. connections about every 20 or 30 ft. for the purpose only of blowing out the line in case of stoppage. During the period of several months that the transport line has been in operation there has been no occasion requiring the use of these connections.

Powdered Coal Burning Equipment.

Since powdered coal is provided as an auxiliary fuel, it is not contemplated that it be used continuously to the extent of the capacity of the burners which are designed to generate 200 per cent of the boiler rating.

Each boiler is equipped with a storage bin of 20 tons capacity which is sufficient for approximately 24 hours supply at the average rate of operation, or about 5 hours supply at the burner maximum rating, so that the operation of the pulverizing plant can be continuous until all the bins are filled and then shut down. The pulverizing plant, with a capacity of 10 tons per hour operates on one turn per day to meet the average boiler requirements for 24 hours. The storage bins are equipped with automatic signal lights operated by small diaphragms inside the bins which cause the lights to signal when the bins are empty and full. Hand operated indicators are also provided for gauging the contents of each bin. A 1000 lb. capacity hopper scale is used for weighing tests of powdered coal as it is delivered from the transport pipe into the boiler bins.

Fig. 3 gives a cross section through the boiler plant which is located between the Rust boiler plant and the turbo blower station, and shows the relative position of boilers, gas main, gas burners, powdered coal bins, powdered coal burners, air main and blowers, and the ash handling cranes.

Five boilers are each equipped with vertical powdered coal burners with individual screw feeders driven by 1 hp. variable speed motors. Powdered coal is fed from the 20-ton bins into a mixing chamber, each supplied by a 6 in. air pipe, and then passes on to the burners.

The burners enter the top of the combustion chamber through a flat suspended arch. The coal on entering the burners, carries with it about 40 per cent of the air required for its combustion as a carrying medium, the balance of the air being admitted through eleven 12 in. circular openings with dampers in the front wall and through air inlet doors on the burners. Exceptionally good results have been obtained from the special design

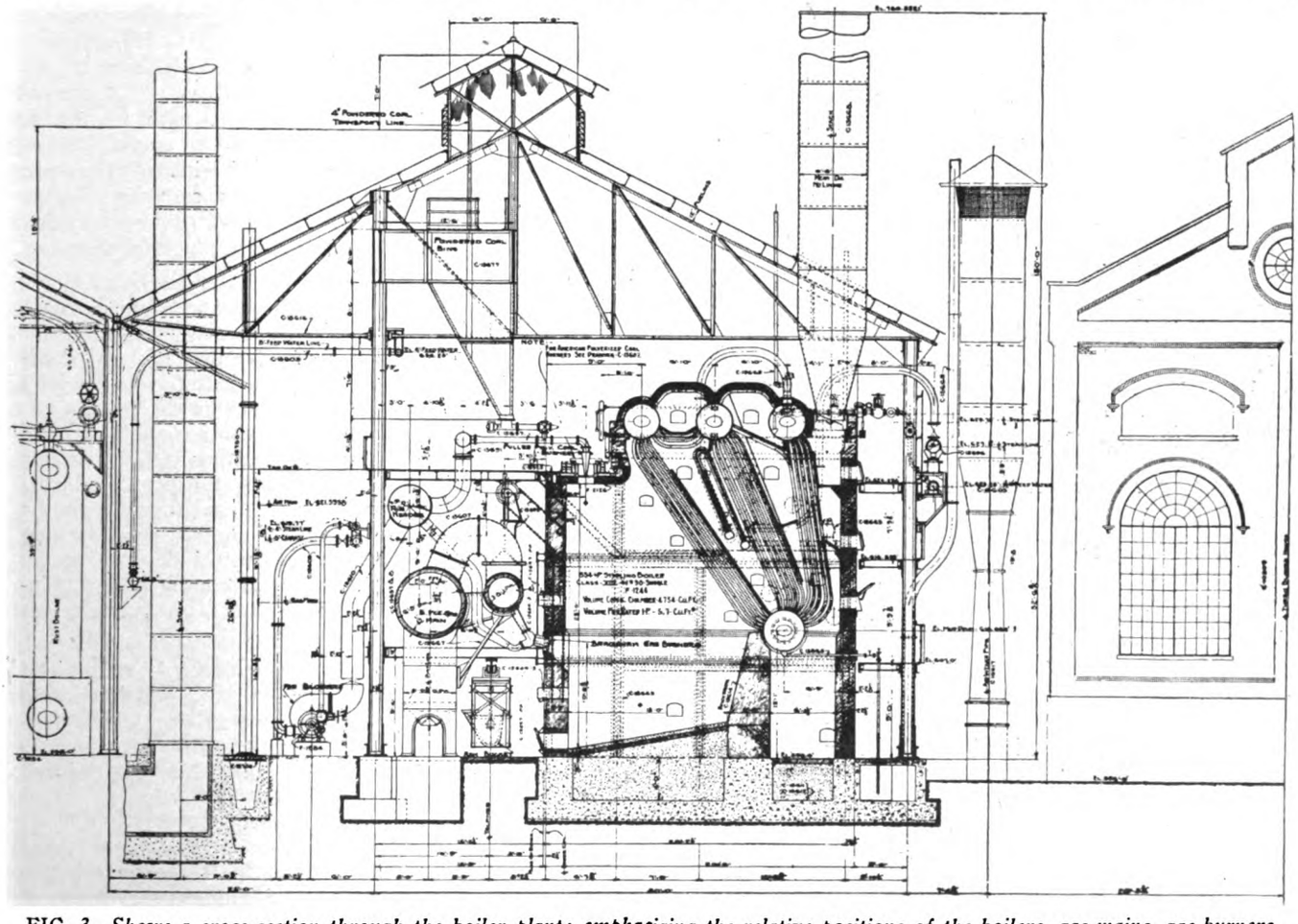

FIG. 3—*Shows a cross-section through the boiler plant; emphasizing the relative positions of the boilers, gas-mains, gas-burners, powdered coal bins, coal burners, air main and blowers, also ash handling crane.*

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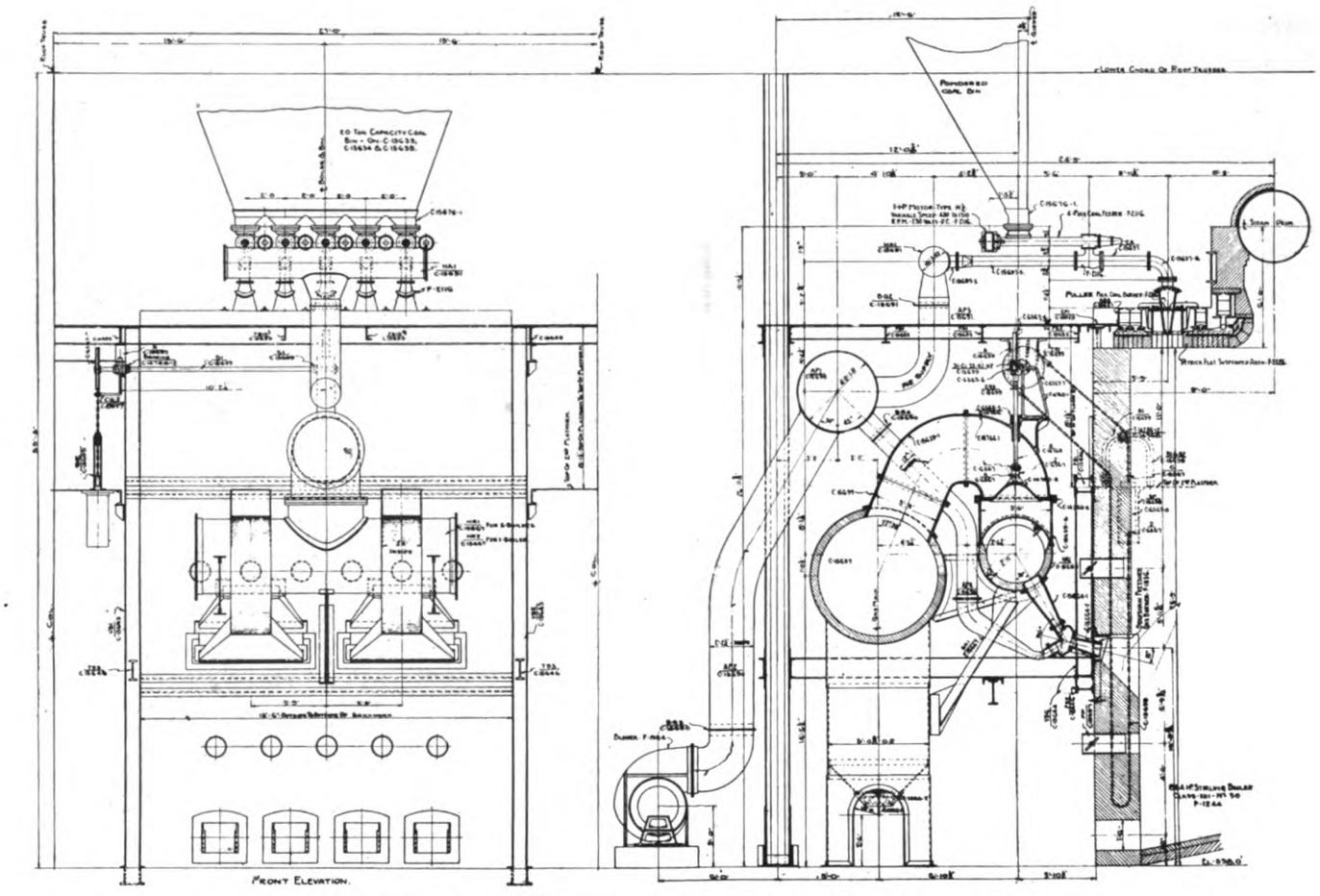

FIG. 4—*Side and front elevations showing gas and coal burner arrangements.*

of the combustion chamber which is unusually large, having a volume of 5.7 cu. ft. per boiler rated hp. The boilers are mounted higher than for customary practice giving a height of about 25 ft. in the combustion chamber, thus enabling a complete combustion of powdered coal and reducing the amount of ash deposit.

The powdered coal feed drives, air supply to the burners and the air inlet dampers for the entire five boilers are automatically controlled through a system of levers by a master control shaft located horizontally above the boilers. This shaft is operated by the movement of a 5 in. master regulator actuated by pressure of the main steam header. The automatic rigging for each boiler unit can be detached and operated by hand if necessary.

Fig. 4 shows side and front elevation of the powdered coal burners and connections as supplied to five boilers.

The sixth boiler is equipped with four low pressure powdered coal burners. The feeding device for these burners is similar to those installed on the other five boilers, excepting that all four feeders are driven by one 7½ hp. motor with a variable speed transmission set which is interlocked with the air supply valves. About 50 per cent of the air required for combustion enters with the powdered coal, the balance being admitted through the eleven 12 in. circular openings with dampers in the front wall as previously described for the burners. The air inlet dampers are connected to a shaft and operated by a hand lever. No automatic control was installed in connection with this unit.

Gas Burning Equipment.

Each of the six boilers is equipped with two pressure type blast furnace gas burners, with a capacity to generate 200 per cent of the boiler rating. These burners, as will be seen in Fig. 3, enter the combustion chamber through the lower front wall.

A proportional supply of gas and air to the burners is maintained, regardless of the gas pressure and amount of gas being consumed, by a relative operation of dampers located in the gas and air connections of the burner body. This relative operation, after the proper adjustment is made, is automatically controlled to suit the fluctuating gas pressure, by an operating rigging similar to that just described for controlling the powdered coal burners, and consists of a lever rigging connected to the dampers and operated by a master control shaft serving the entire six boilers. The master control shaft is rotated by the movement of a 5 in. special combustion regulator actuated by the pressure in the blast furnace gas supply main.

An air pressure of 6 in. water column is maintained in the supply line to the gas burners and powdered coal burners by a 2 in. blowing engine regulator which governs the steam turbines driving the fans. Air supply to the powdered coal burners on boiler No. 6 is reduced to one inch water pressure by a pressure reducer.

Boiler Accessories.

In the auxiliary equipment for the boilers are incorporated several new features of modern development

(Continued on Page 88)

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Precision Welding

One More Step Important in the Evolution of Electric Welding

By S. W. MANN*

ELECTRIC arc welding is just beginning to come into its own. There was a time not so long ago when manufacturers would ask, "Can we take a chance and weld it, the cost being so much lower than bolted or riveted construction?" Today the question is, "Shall we play safe and weld it?" Invariably the progressive and experienced man who really knows welding and knows the causes of failure, together with the principles of successful welding, never even asks himself the question but goes ahead and welds it, because he knows it is stronger, more rigid, more economical and has a better and neater appearance. The various methods that are not in use and the new methods that are yet to come, together with a steadily increasing application to industry at a tremendous saving and increase in safety, are forcing general recognition.

The welding art has so many branches and is growing so rapidly, that the expert must be a specialist. The writer is, therefore, content to follow one method and to apply himself to the promotion of that one particular branch. The electric arc method has been selected primarily because of its flexibility and practically unlimited application and economy. The writer's particular purpose here is to call attention to what can honestly be called precision welding. When we say "precision," we mean precisely that—not almost correct, but within two thousandths of an inch. It was not so long ago that even the machining of a large crank shaft to two thousandths of an inch tolerance was not an easy problem, especially when its assembled or complete weight was between five and 75 tons. Today however, this is the standard tolerance and is lived up to by reliable engine manufacturers.

It is now possible, through the use of precision instruments, that are capable of measuring the alignment of a shaft that is assembled in an engine frame, and the electric arc process, to repair or straighten a broken or twisted shaft or a broken casting to the same degree of strength and accuracy as that required by the manufacturer. Not only is it possible to weld to such fine measurements, but we are limited to the tolerance of the shaft itself. It can readily be understood that we cannot line up a piece of machinery any closer than its machined surface, but the precision obtainable by the use of electric arc welding is practically infinite, there being no practical instrument capable of measuring the fineness of deflection obtainable through the use of the electric arc. We can, to a considerable degree, correct machining faults in large machined pieces, even after considerable use, and when age, with its normalizing influence has caused a warpage or springing of the crank shaft, due to original forging strains, we can straighten the shaft within its original tolerance at a very small cost of labor. When we say "equal to the original tolerance" we do not mean in one particular measurement, but in all of them, of which there are many on a multiple throw shaft. Its warped condition, after use and age, is produced by the natural tendency of the original forging strains to neutralize or equal one another. As a result, a shaft that might have been machined to a tolerance of one thousandth of an inch may, in the course of time, even though it be kept in storage, incur a warpage of 10 to 15 thousandths.

The classes of work coming under the head of precision jobs not only include crank shafts of steel but cast iron or cast steel as well and the term can be employed wherever a large mass of steel requires bending, straightening or twisting. The crank shaft may become twisted in various ways. It may be that the fly wheel of an engine is suddenly stopped. The inertia is liable to twist the section between the fly-

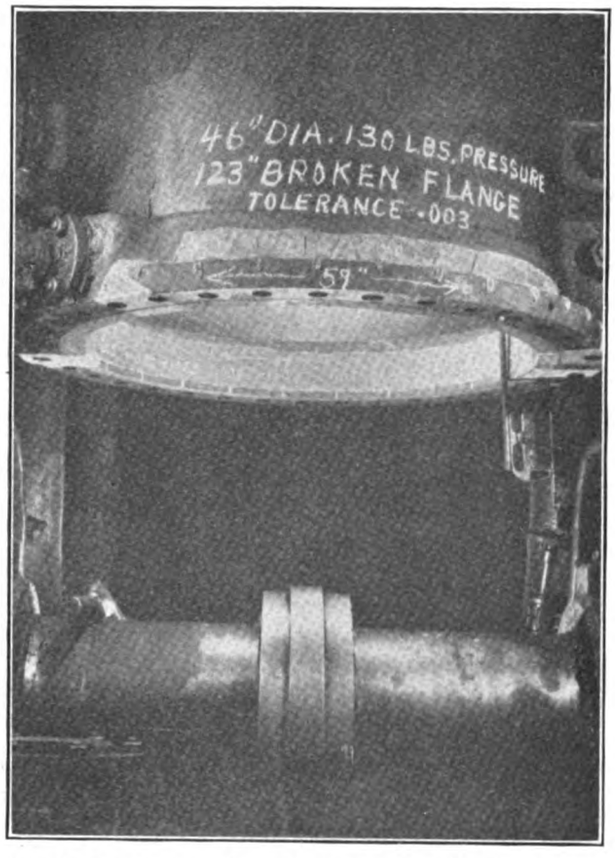

FIG. 1—*Completed weld on broken flange of 46-in. diameter blowing engine cylinder.*

wheel and the crank throw or counterbalance weights, or in another instance, the cylinder may, during the course of starting or stopping the engine, come up against a water head and in that case, the inertia of the fly wheel would produce a tendancy to twist the shaft. In multiple throw engines, we have on record cases of broken connecting rods or piston rods that caused sudden stopping of one particular throw and the momentum of the balance of the moving parts produced twisting in one or more places. This twisted

*Kleinhans Company, Pittsburgh, Pa.

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condition can also be overcome by the electric arc, within certain limits, of course.

Suppose a high pressure cast iron cylinder should have its whole flange broken off completely around the cylinder, due to a broken or loosened piston rod or water head. Although a delicate problem, it is a practicable undertaking to replace this flange on all cylinders over two feet in diameter and also to have all of its gasket face tolerance equal to the original. In undertaking work of this nature a complete practical knowledge and understanding of expansion and contraction of metals is necessary. A technical knowledge is desirable but not a necessity. The operator or supervisor must thoroughly understand the use of precision instruments, some of which he must be capable of devising himself to suit the individual problem confronting him. The electric arc method is the only method that can be employed to a satisfactory degree and should be a direct current welding circuit. Low voltage is preferable due to its limiting the possibility of burned or porous metal caused by the long arc. The welding current should not exceed 150 amperes and should be well regulated so that it can be held constant at all times, regardless of the variations of the arc length due to the human element. Such control of the current means that regardless of the area of the weld or puddle of molten metal under the arc, the heat per unit area of this puddle will be constant.

The process and method of repairing the crank shaft shown in the accompanying photographs is known as the Neutralized Precision Weld and this shaft in particular, when completed, was under a tolerance of 1¼ thousands of an inch. The process in this and similar work is briefly as follows:

The fracture, whether it lays directly in the crank pin, main shaft or web of a shaft, should be chipped off from the opposite sides, where possible. In a round section, it should be chipped to a point, leaving a "V" of approximately 90 deg. between the two pieces when they are assembled. The metal should be thoroughly clean and free from carbon pockets or shrinkage cracks before attempting to weld. The two parts are then placed together with the points of the "V" or chipped section in line with each other and with an opening between them of ⅛-in. or more, so that complete fusion of the added metal with either side of the "V" may be obtained.

The next step to be taken is the alignment of the work which, without question, is the most difficult problem encountered in the whole repair. Provision must be made in the original alignment for shrinkage of the metal in the primary weld tacking the two pieces together. When this alignment has been completed and the connecting weld is made, check measurements should be taken from all angles. It is often found that the shrinkage of the tacking weld is greater or less than anticipated and within reasonable limits, such errors can be corrected by the use of a peening hammer to affect an expansion, or, if contraction is required not exceeding three or four thousandths of an inch, the application of one additional layer may give the desired result. In no case should a contraction be allowed to remain in more than two layers of the original connecting weld. When the error in alignment exceeds three or four thousandths in either direction, good practice makes it necessary to chip out or break through this original weld and then start over again. The operator may have to repeat this operation many times before an absolute

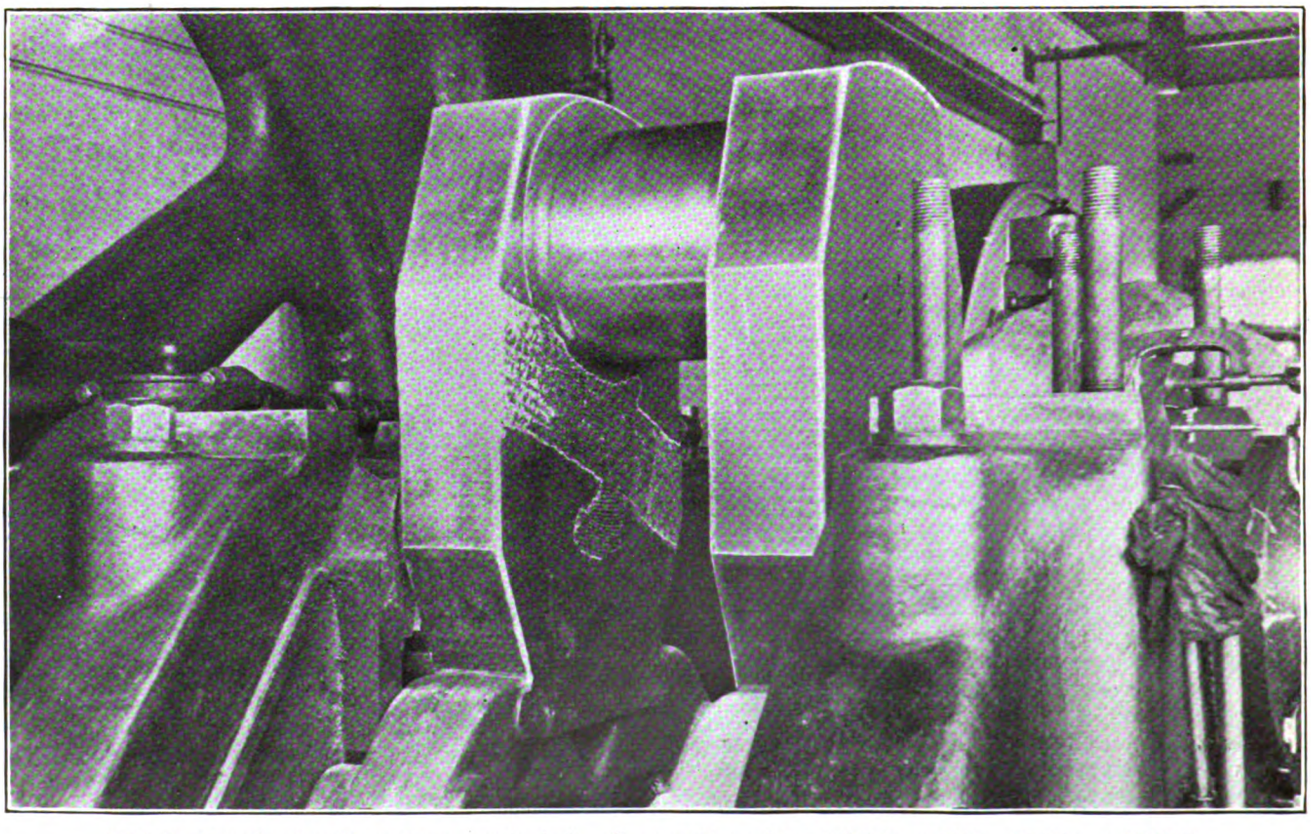

FIG. 2—*Completed weld on large crank shaft. Cross-section of break 5¾ in. x 22 in. Tolerance .00125 in.*

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zero point is obtained. When this has been accomplished, the difficult part of the job is past.

The process from then on consists solely in the repeated application of single layers of metal on all sides of the weld. If desired each layer may extend over the whole fractured surface. Shrinkage strains, which will be set up in each layer, are removed by the use of a peening tool. Additional metal must not be applied at any time until all shrinkage of the metal already deposited has been relieved, so that all indicators reach zero. It is advisable, during the application of a layer, to occasionally watch the indicators to acquaint oneself with the location and the amount of the actual stresses. By continued observation of the micrometers along with the welding, a perfect understanding of contraction can be obtained. This same observation is advisable during the peening process so that the operator may familiarize himself with the actual amount of peening required to affect a neutral weld. The understanding of contraction and expansion, as above outlined, will, in the course of a short time, enable the operator to estimate very closely the amount of peening necessary on work where the use of precision instruments is not practicable and should prove a very valuable asset to any operator.

The extent of contraction varies considerably and usually is in direct proportion to the variation in carbon in the electrode metal. As is readily understood, contraction stresses set up by a hard high carbon metal will produce more of a deflection or shrinkage than those of a soft metal, and the hard metal also requires an additional amount of peening to accomplish the neutralization. Any deflection sideways in the welding of the crank shaft may also be corrected by peening. It is absolutely essential that no more than one layer be applied over the entire surface of any precision weld before peening. It is definitely proven that the expansion produced by the miniature forging blows of a pneumatic hammer do not forge the metal any deeper than ¼ in.

The expansion of a second layer on top of a layer that has been applied without peening, will merely create additional tensile stress severe enough to probably cause an invisible fracture in the underlying layer. There are also times when, due to the thickness of a layer, along with its hardness from the use of a particularly hard metal, the contraction stresses cannot be relieved until continued peening has flaked off a certain amount of this surface of the weld. It is a fact that when a thin layer of white hot metal is homogeneously applied to colder metal, it sets up tremendous strains, and, when applied with a thorough knowledge, can be used to accomplish desired distortions in large steel sections that cannot be obtained in any other manner. It is also acknowledged that this thin layer of metal which has tied up in itself thousands of pounds of pull created by contraction, can readily be normalized or expanded to a normal condition by the means of the forging effect of a peening hammer. Layer upon layer may be applied and treated with micrometers or indicators as gauges, with absolute confidence that, if carefully and accurately done, the finished mass of metal will be absolutely normal or neutral with neither expansion or contraction stresses, thus doing away with the necessity for annealing.

There is also good reason to believe that the forging effect of a hammer increases the ductility and tensile strength of the metal in the same manner as the forging of steel. The full value of the peening process might be compared very favorably with steel forging, insomuch that it flattens out the individual grains of metal and produces an amalgamation between these grains, that is lacking in the original weld. It is definitely known that a grain of pure steel is surrounded by a shell of impurities. In the event of a fracture, it will follow the line of impurities between each grain and does not have to break through the center, which is the pure steel. By peening or forging, this grain is so flattened that it takes on an over-lapping layer effect and the fracture has to make its way through layer after layer of pure steel.

Not only does the peening produce an increased strength, but it makes possible a neutral weld and also the process of obtaining precision welding.

When it comes to cast iron welding, the welding world, as a whole, is more or less under the impression that studding of the welded areas is absolutely essential as a safety factor. In reality, where studs are applied without the peening process, they merely help to strengthen a faulty weld. We do not disapprove of studding as we have determined that it is an advantage even when employed in a neutralized or peened weld, inasmuch as it anchors the contraction of the original bounding layer and permits a greater area of metal to be welded before peening, without danger of contraction becoming great enough to affect a fracture through the thin layer of chilled cast iron directly under the juncture line. We have, in a number of cases where we have had ample time to complete a job, welded cast iron entirely without studs, but when this process is followed, it is necessary to peen every square inch of the metal as it is applied. If this is not done, the strains set up parallel with the weld will be great enough to fracture at the puncture line. We have proven through numerous tests, that the section which usually cracks directly under the chilled area is of higher tensile strength than the actual cast iron itself, but the sheering strains set up at this point, due to the tremendous amount of contracting, is great enough to produce a fracture, even though it had a tensile strength of three or four times the original casting. In cases, where we have followed out the peening theory of one inch at a time, we have accomplished very successful welds without the use of studs, having a parting strength greater than the iron itself.

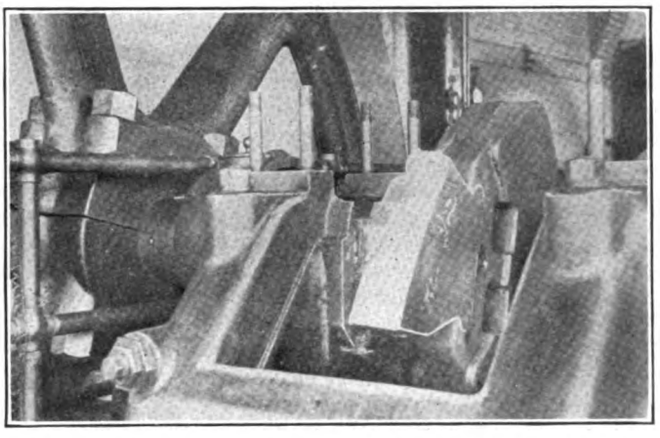

FIG. 3—*Part of broken crank shaft prepared for welding.*

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In making the above statements, it is naturally assumed that the correct welding material is used and on cast iron, there is no one or two welding wires that will satisfactorily fuse with every piece of cast iron. We might also add that the welding rod is, without question, a very important item and should be given as much consideration as the operator or the machine. In fact, successful welding may be divided into three parts of very nearly equal importance—the operator, the machine and the wire. Very often it is found that with the very best of equipment welding results are not satisfactory due to the use of an inferior welding electrode. In another instance, the electrode and material may be of first class quality, and the operator is not of the interested and progressive type.

In stock today are carried possibly six or seven different grades of wire for use on cast iron and it is usually possible to find one among this assortment that successfully gives a perfect fusion with cast iron. Castings that are older than 20 years have been found in several cases, to contain a considerable excess of phosphorus or sulphur. At times, it requires considerable experimenting to produce a counteracting chemical to overcome the detrimental effects of an excess of sulphur or phosphorus.

When one stops and really figures out the tremendous shrinkage strains set up in a cast iron weld having a cross section of five inches or more, and it is realized that most such welds have been made without provision for relieving the strains, one is not surprised that the welding of cast iron has not generally met with commercial success.

It is very gratifying to know that in the last three years, during which time I have directed numerous cast iron welding repairs, not a single failure has developed and this unequalled success is layed directly to the neutralizing process. This work has been done on castings having a cross section as high as 10 inches and with weights running as high as 90 tons per unit. In all welding work undertaken by my company, whether it is cast iron, steel or copper, the work has been guaranteed for a period of one year to meet all of the conditions of the original casting or forging, both as to porosity, strength and precision of alignment.

I have attempted, in this article, to show one of the numerous welding repairs that have been accomplished at a very great saving of both time and money and I know of no company today who is employing in their welding department an electric arc welder that is not receiving service many times the value of the installation.

No longer need haphazard methods nor imperfect welds be tolerated. It is now possible to surround any emergency with a co-operative effort, based on many years of actual welding and engineering experience. An enormous variety of undertakings have been encountered and mastered under every condition that could be conceived.

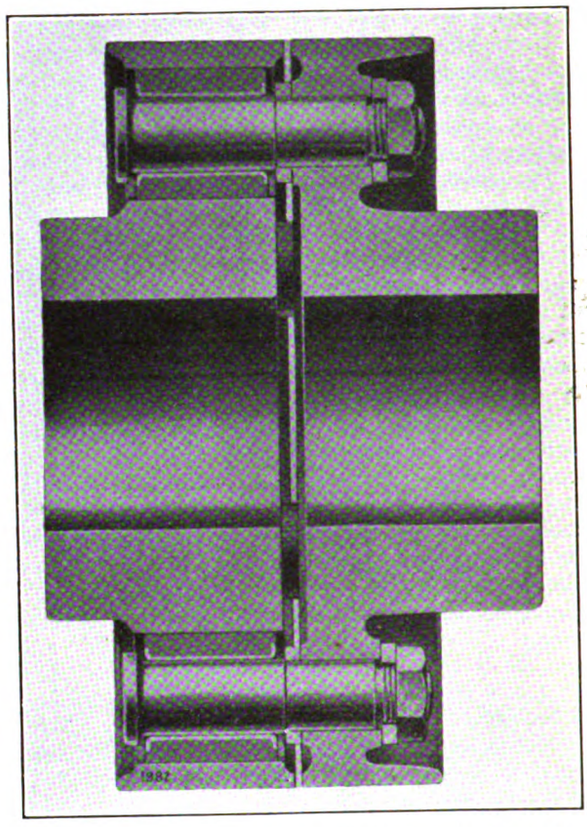
A successful welding organization must offer the following service:

Competent engineers who are capable of assuming the responsibility of complete reconstruction of wrecked machinery or power plants; resources in welding equipment, with unlimited operators ready to meet its largest emergencies assurance that all work must be done on a year's guarantee.

These basic factors combined raise electric welding to a successful art.

Flexible Coupling Described in Bulletin

The DeLaval flexible coupling is described in a 12-page pamphlet issued by the DeLaval Steam Turbine Company of Trenton, N. J. This coupling, which has been developed for turbines and similar machinery, consists of two opposed flanges mounted on the driving and driven shafts respectively. One flange carries bolts or pins which enter holes bored in the opposing flange, but not coming into metallic contact with the latter, as the driving force is transmitted through steel lined molded rubber bushings slipped over the



pins. The rubber supplies the flexibility required to take care of inevitable slight misalignment, does not require lubrication, absorbs shocks and is long lived and reliable. There is no constraint upon independent endwise motion of the shafts and one shaft can be removed without disturbing the other. The peripheries of the flanges are ground to true cylinders and the faces to true planes to facilitate lining up. All parts are made to limit gages and all similar parts are interchangeable.

New Bulletin Describes Motorbloc

Bulletin S-101 issued by the Motorbloc Corporation of Philadelphia, describes and illustrates the application of the Motorbloc in several capacities as developed by the results of 18 years' experience in the material handling field.

A tabulation of capacities, speeds, weights and electric motor sizes is given on page three.

The principle features of value to the user are lightness and portability and a motor operated chain block that can be furnished in all capacities and operated by a small electric motor built into a compact unit that can be used anywhere electric current is available in connection with a Pendant Controller furnished with it.

Copies of this bulletin will be gladly sent to any manufacturers or dealers who may be interested to use or sell this new labor saving device.

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Some Pointers on By-Product Coke Oven Operations

Installing Simple and Modern Ash Handling System at Homestead

There is little money to be made from ashes in a modern boiler house. It appeals much more strongly to the average engineer to think along the lines of fuel saving. In consequence, there is a tendency in the building of new boiler houses to study and investigate in infinite detail questions of boilers—type, size and setting in its relations to furnace efficiency; the question of stokers and their combustion efficiency. The ashes are a necessary nuisance and it is perhaps too vaguely thought that they will be manhandled out of the plant in some way.

A little consideration along the following lines, however, will indicate the importance of the proper ash handling facilities. Consider the boiler house such as Carnegie Steel Company at Homestead is now installing, eight approximately 1,000 h.p. boilers. It is reasonable to suppose that six of these boilers will normally be operated at an average rating of 200 per cent. The plant will therefore generate 12,000 boiler h.p. continuously, although capable, under peak conditions, to perhaps double that capacity for limited periods.

On the basis of 3½ lbs. of coal per boiler h.p., this will mean 42,000 lbs. of coal burned per hour. On the assumption of 15 per cent ash or other refuse, by weight, this will mean 6,300 lbs. of ash per hour or, for even figures, say three tons. At 24 hours per day, it means 72 tons. If this ash is inefficiently handled, it may cost as high as 50c per ton to get same into railroad cars for final disposal, whereas if it is efficiently handled, it can be done for 10c per ton. In other words, the difference between efficient and inefficient handling of ashes in such a boiler house will amount directly, in dollars and cents, to a saving, by an efficient method, of approximately $10,000.00 a year.

This is only part of the story. Improper ash handling layouts and apparatus produce conditions for ash handlers under which it is almost impossible to work. The labor turn-over is often tremendous and the wages demanded, high.

Improper working conditions because of improper apparatus in the ash tunnels resulted in many serious accidents; burning or asphyxiating by monoxide gas, of labor have been and still are all too frequent an occurrence.

The following features of this arrangement are considered particularly good:-

The ash will dump by gravity into the hopper and again by gravity into an electrically operated lorry car. The gates controlling the flow of ashes into the lorry car are power controlled. In consequence, they can be opened and shut almost instantaneously at the will of the operator with no more manual labor than the turning of a four-way cock.

The lorry car will unload into a skip hoist which in turn will unload into storage means over railroad cars. After one or more day's supply of ashes have been stored, hopper cars are spotted beneath, the material dropping by gravity. The approximate cost of handling the ashes with such a system as this will be 10c per ton. The entire system is extremely simple, requires only a single man for operation and all the ashes can be handled by part of this one man's time in a single shift.

The hoppers used are of cast iron as cast iron will stand up almost indefinitely under the action of sulphurous water. It is therefore best suited for the service. Note that the walls of this hopper are nearly vertical. In consequence, it is impossible for the ashes to arch over the opening as there is no skewback upon which the ashes can rest. They therefore drop by gravity from the hopper into the car. There is no manual hoeing or poking. The hopper is tile lined. Notice that the tile lining in the vertical wall of the hopper is locked by gravity to the side of the hopper and cannot fall into same.

Another interesting feature is that the quenching water leaders are run entirely outside the hopper and the water introduced by quenchers set into the hopper walls. It is claimed that this arrangement will more adequately cool and make dustless the hopper contents with a mere fraction of the water as compared to the old scheme of running a perforated pipe directly through the hopper. As none of the apparatus is within the hopper, the depreciation is virtually nothing. The quenchers are so arranged as to be accessible from the outside.

Another interesting detail is, this quenching water is collected and discharged to drain, maintaining a clean, dry ash basement. Most boiler house operators are familiar with a deluge of water which comes down from the ash hoppers when the ashes are being quenched. It results, in cold weather, in an accumulation of ice and slush under foot, with a heavy fog continually hanging in the tunnel. At all times of the year, it means that the ash handler must take a good drenching every time the ashes are handled.

Another feature of interest is that the ash gates themselves use the quenching water for a water seal. It is therefore impossible for monoxide gas to leak from the hopper into the tunnel and this menace to life is therefore eliminated. The arrangement also improves combustion efficiency as excess air cannot leak around the ash gates and enter the furnace through the stoker dumps.

Considerable credit is due to the engineers of the Carnegie Steel Company for the thorough way which the details of this installation have been worked out. The Allen-Sherman-Hoff Company of Philadelphia furnished the cast iron hoppers and power operated gates, as well as the special ash quenching apparatus.

Spacing of Pipe Supports

(Continued from page 53)

"S," if the deflection is not too great, then the span as given by the table is satisfactory; if the deflection is too great (as shown by the table) choose a span of satisfactory deflection, by the table, even though the "S" for this span is less than as calculated.

For instance, "S" in "7-d" is 3800 lbs. for 8-in. dia., which falls between 22 ft. and 24 ft. span (this being for a thinner 8-in. dia. pipe than for item "7"); therefore we would choose a 22-ft. spacing, with a deflection of only 0.209 (for a thinner pipe than for item "7"), which is less than the 25 ft. spacing per "7-c" and "7-d" and is on the safe side.

Having determined the spacing of the pipe hangers or supports, the piping may be carried on existing structures, as in the following Case 1, or special structures may be required. In the case of long spans or runs of piping through work and mill yards the following Cases 2, 3 and 4 show very desirable construction and the formulae for the design.

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Fred C. T. Daniels, metallurgist for the Wheeling Mold & Foundry Company, Wheeling, W. Va., has recently severed his affiliation with the Wheeling organization to become superintendent of the roll department of the Bethlehem Steel Company, Bethlehem, Pa. Associates of Mr. Daniels looked upon his leaving Wheeling Mold & Foundry with a sense of keen regret, as he had been with the company since 1914 and had the responsibility of a most important unit of the organization. Mr. Daniels is, however, eminently fitted for the larger responsibilities which he will be called upon to assume in his new field, and there can be no doubt as to the success he will merit. He is a graduate of Worcester Institute of Technology, Worcester, Mass., and has had much experience in roll manufacture and rolling mill practice, in and about the Pittsburgh District. He holds patents on several alloy mixes which have proven their worth in roll manufacture as well as in other lines of the alloy casting trade. The vacancy in the metallurgical and roll department of the Wheeling Mold & Foundry Company, caused by Mr. Daniels leaving, has been filled by R. C. Heaslett, who has been chief chemist for this organization since 1916.

Announcement has been made by Director Edward R. Weidlein of the appointment of Dr. Warren Fred Faragher as an assistant director of Mellon Institute of Industrial Research of the University of Pittsburgh. Dr. Faragher, who has been a senior industrial fellow of the Institute since 1918, is a specialist in the chemistry and technology of petroleum and has made a number of important contributions to the chemical knowledge of hydrocarbons. He assumed his new office on December 1 and his successor on the research staff of the Institute's petroleum investigation will be Dr. William A. Gruse. Of special interest is the fact that Dr. Faragher, who received his professional training at the University of Kansas, was selected by the late Dr. Robert Kennedy Duncan as the incumbent of the first industrial fellowship established in that institution in 1907. Later, in 1911, Dr. Duncan came to the University of Pittsburgh, and his industrial fellowship system is now the basis of the work of Mellon Institute. Following the completion of his researches at the University of Kansas, Dr. Faragher spent nine years in the industrial field as a specialist in oils, and in 1918 he was appointed a senior fellow of Mellon Institute. In addition to his research accomplishments, he has been constantly active in furthering the interests of the American Chemical Society and the American Society for Testing Materials.

Clinton G. Armstrong, formerly consulting metallurgist for the Chicago Flexible Company, and research metallurgist of the Western Electric Company, has joined the Calorizing Company. He will serve in the capacity of sales engineer and will be connected with the Chicago office of the Calorizing Company.

R. T. Haslam has been promoted to a full professorship at the School of Chemical Engineering Practice, Massachusetts Institute of Technology, Cambridge, Mass.

Professor Haslam's translation of the article, "The Production and Utilization of Producer Gas for Heating Open Hearth Furnaces," appeared in May and June issues of this magazine.

A. H. C. Heitman has resigned as general manager of Chemical Products, Ltd., Trenton, Ontario, manufacturers of sulphuric acid and heavy chemicals. He was for some years a member of the research staff of Parke, Davis & Company. Before coming to Trenton, he was manager of Chemical Products of Canada, Ltd., Toronto, producing a variety of products, heavy chemicals, as well as pharmaceutical synthetics. Mr. Heitman was recently appointed a member of the Chemical Committee of the Honorary Advisory Council for Scientific and Industrial Research, Canada.

F. W. Miller, superintendent Sloss By-Product Plant, Birmingham, Ala., addressed the Nashville Section, December 21, on the "Modern By-Product Coke Oven."

The Electric Furnace Construction Company, Philadelphia, advise the following recent installations of their equipment: Henry Disston & Sons, Tacony, Pa., electric heated furnace for continuous hardening and tempering of band saws; Dodge Steel Company, Philadelphia, Pa., rapid melting acid lined electric furnace for steel castings; Armstrong Company, Huntington, W. Va., continuous electric vitreous enameling furnace; Panama Canal, Cristobal, C. Z., electric steam boilers (Kaelin system); Ford Motor Company, Green Island, N. Y., two electric steam boilers (Kaelin system); Aviation Department, McCook Field, Dayton, Ohio, electric heat treating furnace. Work under construction includes electric steam boilers for Chile, Guatemala, and rapid electric melting furnace for cast iron for the Owens Bottle Company, Toledo, Ohio.

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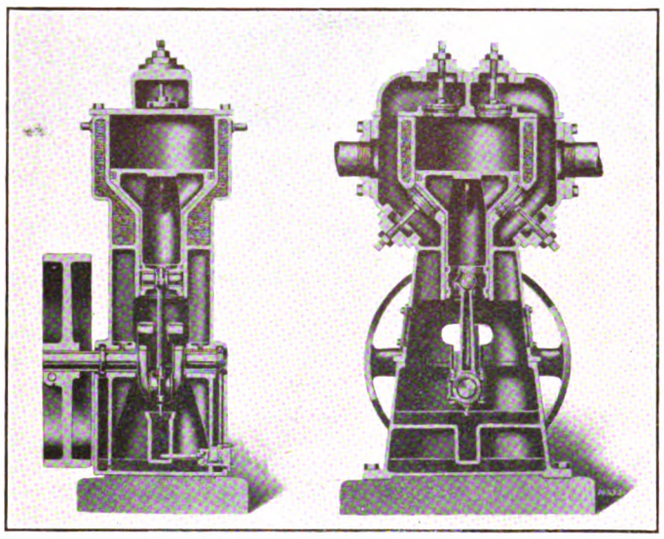
WITH THE EQUIPMENT MANUFACTURERS

New Line of Small Vertical Vacuum Pumps

The Ingersoll-Rand Company, 11 Broadway, New York, announces a new line of small vertical belt driven vacuum pumps, known as Type Fifteen. This should be of particular interest to those users who require high grade, standard, reciprocating, dry vacuum pumps of small capacities. The wide range of sizes and the different methods of drive offer a vacuum pump to suit any need where a high vacuum is necessary. Type Fifteen vacuum pumps will pull and maintain vacuums between 28.6 in. and 29.25 in., depending on their size. In addition to the standard belt design each



size is built as a self-contained electric motor outfit, using the short belt drive arrangement or driven through pinion and internal gear. The vacuum pump and electric motor of both the short belt and gear driven units are mounted on a metal sub-base, so that they are not dependent on the foundation for correct alignment.

The "constant-level" system of lubrication used on the Type Fifteen vacuum pumps maintains a constant-level of oil, which insures the right amount being distributed to all parts. Like in the ordinary splash system, the bottom of the pump base forms an oil reservoir of sufficient capacity for the "constant-level" system. The amount of oil in this reservoir is determined by high and low level pet cocks. Above the reservoir and directly underneath the connecting rod is a constant level pan (lubrication holder), into which the connecting rod dips and distributes just a sufficient quantity of oil for proper lubrication. The constant level pan is replenished with oil from the supply in the crank case by a valveless oil pump operated by an eccentric on the main shaft. Regardless of the amount of oil in the reservoir, so long as it is somewhere between the high and low level petcocks, this system will function properly. The lubrication of small vertical vacuum pumps employing the enclosed crank case and splash system has often been a source of great concern. The tendency of oil systems has been to feed either too much oil, which will be carried out with the air, or too little, causing scored cylinders, overloads and burned out bearings.

There are six sizes—the 2x4 in., 3x5 in., 4x6 in. and 5x8 in. single acting pumps; the 5x10 in. and 6x12 in. double acting pumps. The 2 in., 3 in., 4 in. and 5 in. stroke single acting pumps are air cooled by means of an annular ring which encircles the cylinder, while the 5 in. and 6 in. stroke double acting pumps are cooled by means of circulating water.

An illustrated descriptive bulletin has been issued on these vacuum pumps which describes in detail all their new and improved features. The manufacturer will be glad to send a copy to anyone who is interested.

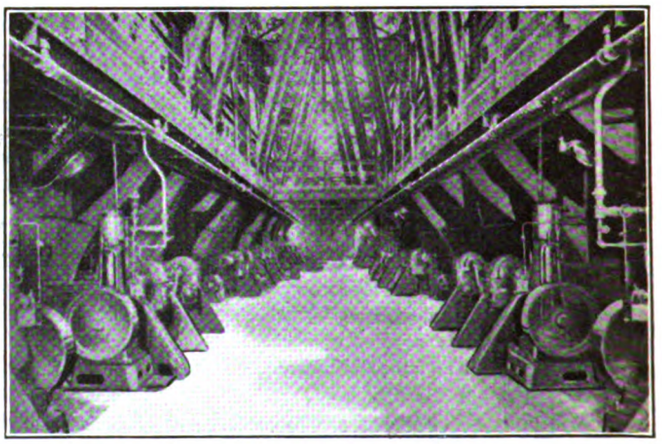
Riley Underfeed Stokers

Riley Underfeed Stokers are described and illustrated in detail in a new bulletin No. 92.

These are mechanical stokers of the multiple retort, underfeed type for high duty service. Particularly adapted for extreme, sustained overloads and fluctuating steam demands. Save 10 to 25 per cent of coal over hand firing, also make possible use of inferior grades of coal. Eliminate drudgery from boiler room and make a clean boiler room possible. These two factors attract high grade and intelligent operators. Reduce boiler room labor to a minimum. High capacity obtainable together with quick response to overloads reduces the number of boilers required, with corresponding decrease in investment, maintenance and operating expense.

This catalogue describes in detail the engineering features of Riley Stokers (many of them exclusive), that enable them to attain these results in an efficient, economical and reliable manner, and give satisfactory service that has led to the use of Riley Stokers in all parts of the world.

Riley Stokers are multiple retort, inclined, underfeed stokers—that is, the fuel is forced up from beneath the point where the air is admitted, and is then burned on a series of inclined retorts. Distillation of the volatile gases takes place in the retorts, after which these gases, mixed with air, pass through an active bed



of burning coke and then through the incandescent fire zone.

The Riley Stoker, however, differs from all other underfeed stokers. Instead of stationary tuyeres it has moving, air supplying grate blocks, carried by the reciprocating sides of the retorts. These retort sides also move the overfeed grates which extend across the entire width of the stoker below the retorts. Beyond these are the rocker dump plates, which continuously agitate, crush, and discharge the ash. The travel of these reciprocating parts is adjustable so as to control completely the movement of the fuel bed and dumping of refuse.

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NEWS OF THE PLANTS

The Republic Iron & Steel Company, Youngstown, Ohio, has plans in progress for the construction of two new tube mills at its local plant on Poland Avenue, and proposes to commence work at an early date. Extensions and improvements in other departments have been commenced and will be pushed to completion. These include the rebuilding of a portion of the Bessemer works, replacing present equipment with more modern and improved machinery; the installation will provide for considerable increase in capacity at the unit. Similar changes are being made in the billet and bar mills, where electric operation will be substituted for the former hydraulic-driven equipment. The reconstruction of a blast furnace at the Haselton division is also under way, and it is expected to complete this work in the near future, to include the installation of an additional battery of coke ovens, as well as other minor work for greater efficiency in service. The expansion and improvement program is estimated to involve in excess of $350,000.

The Pacific Coast Steel Company, San Francisco, Cal., has exercised its option to purchase a tract of property near Long Beach, vicinity of Los Angeles, Cal., totaling about 200 acres of land, heretofore held by the Los Angeles Dock & Terminal Company, giving a consideration of about $2,000,000 for the property. It will be used as a site for a new steel mill and blast furnace, on which work will be inaugurated at an early date. The furnace will be the first unit to be built, and will be of thoroughly modern type, with capacity of approximately 600 tons. The structure is estimated to cost about $5,000,000, including auxiliary departments. Other structures will be erected closely following, to include rolling mills, tube mills, machine departments, power plant and miscellaneous mechanical buildings. The entire works will represent an investment of close to $15,000,000, complete. The company is represented by T. T. C. Gregory, Insurance Exchange Bldg., San Francisco, attorney.

The Waterbury Rolling Mill Company, Waterbury, Conn., will commence the erection of a new addition to cost close to $75,000, including equipment. It will provide for extensive increase in capacity. A general contract for the building has been awarded to the Tracy Brothers Company, Waterbury.

The Marting Iron & Steel Company, Ironton, Ohio, has tentative plans under advisement for improvements in its local blast furnace, to provide for large increase in capacity, as well as greater efficiency in operation. Details and estimates of cost will be perfected at an early date.

The Truscon Steel Company, Youngstown, Ohio, has arranged an appropriation of $400,000, for extensions in its local plant. A new series of buildings will be constructed on Albert Street, totaling about 100,000 sq. ft. of operating space, to be provided with modern machinery for extensive increase in production of standardized steel shapes and products for construction purposes, approximating from 15 to 20 per cent over the present rating. The working force will also be enlarged. It is expected to have the new structures ready for service early in the coming spring. Julius Kahn is president of the company.

The Hull Steel Foundries Company, Ltd., Hull, Quebec, has acquired property at Ogdensburg, N. Y., and has plans in preparation for the erection of a new steel works at this location. It will consist of a number of one-story plant units, with power house and auxiliary structures, estimated to cost close to $500,000, including equipment. A. H. Coplan is president.

The Blair Strip Steel Company, New Castle, Pa., recently organized, has selected a local site and has plans under way for the construction of a new plant for the manufacture of steel products, including cold rolled specialties. It will consist of a main building, with a number of auxiliary structures, and is estimated to cost in excess of $75,000. It is expected to commence operations at an early date, having the plant ready for service during 1924. The new company is headed by George D. Blair, Sr. and Jr., and J. Norman Martin, all of New Castle, who will be active in the management of the new company.

The United Alloy Steel Corporation, Canton, Ohio, has arranged an appropriation of more than $1,200,000 for extensions and improvements in its plant, including the installation of considerable additional equipment. The work will comprise the rebuilding of two continuous furnaces used for the 12-inch mill, additional soaking pits, new stripper and new gas producer. It is also proposed to build a new power house and boiler plant. Initial operations have been commenced and the entire improvement program will be pushed through to completion.

The American Rolling Mill Company, Ashland, Ohio, is pushing construction on its new bar mill and expects to have the unit ready for service at an early date. Other expansion is also in progress for considerable increase in production and the installation of equipment will soon be commenced. This latter work will be completed during the first quarter of the new year.

The Acme Steel Construction Company, Homestead, Pa., has purchased property in the Wickliffe industrial section, Youngstown, Ohio, and will have plans prepared in the near future for a new plant at this location. It will consist of a main building, power house and subsidiary buildings, with reported cost placed in excess of $100,000, including equipment.

The Brown-Hutchinson Iron Works, 1831 Clay Street, Detroit, Mich., has completed plans and will commence the immediate erection of a new addition to its plant for considerable increase in capacity. It will be one-story, located on Morrow Street, and is estimated to cost close to $45,000, including equipment. The general building contract has been awarded.

Unusual Blast Furnace Boiler Plant

(Continued from Page 77)

in addition to certain makes of standard accessories that have been adopted for general use. Included in this equipment are feed water regulators, furnace efficiency regulators for operating the stock dampers, steam purifiers, soot cleaners, blow-off valves and thermo-couples, pyrometer and recording instruments for furnace and stack temperatures.

CO_2 recorders, indicating steam flow meters and draft gauges are installed on each boiler and an integrating steam flow meter is installed on the main steam line leading from the boilers. A gas flow meter is located in the blast furnace gas supply main and coal meters are provided in the dried coal chutes leading to the pulverizers, so that it is possible to make an approximate check of the efficiency of the plant daily.

Ashes and blast furnace gas flue dust are removed when boiler is down and are disposed of by a traveling telpher equipped for handling a 65 cu. ft. capacity ash pan, and runs on an overhead I-beam track located directly in front of the boilers and extending through the boiler house to the original coal and ash handling station of the main boiler plant.

The operation of this plant has met all expectations and has demonstrated that this method of supplementing blast furnace gas is entirely satisfactory.

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"Experimental Furnace" *continued in* February, March, April

The Blast Furnace and Steel Plant

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